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A STUDY OF COAL MINE HAULAGE IN ILLINOIS

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ILLINOIS COAL MINING INVESTIGATIONS COÖPERATIVE AGREEMENT

(THIS REPORT WAS PREPARED UNDER A COÖPERATIVE AGREEMENT BETWEEN THE ENGINEERING EXPERIMENT STATION OF THE UNIVERSITY OF ILLINOIS, THE ILLINOIS STATE GEOLOGICAL SURVEY, AND THE U. S. BUREAU OF MINES)

BULLETIN No. 132

ENGINEERING EXPERIMENT STATION

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THE Engineering Experiment Station was established by act of the Board of Trustees of the University of Illinois on December 8, 1903. It is the purpose of the Station to conduct investigations and make studies of importance to the engineering, manufacturing, railway, mining, and other industrial interests of the State.

The management of the Engineering Experiment Station is vested in an Executive Staff composed of the Director and his Assistant, the Heads of the several Departments in the College of Engineering, and the Professor of Industrial Chemistry. This Staff is responsible for the establishment of general policies governing the work of the Station, including the approval of material for publication. All members of the teaching staff of the College are encouraged to engage in scientific research, either directly or in coöperation with the Research Corps composed of full-time research assistants, research graduate assistants, and special investigators.

The volume and number at the top of the front cover page are merely arbitrary numbers and refer to the general publications of the University of Illinois; *either above the title or below the seal is given the number of the Engineering Experiment Station bulletin or circular which should be used in referring to these publications.*

The present bulletin is issued under a coöperative agreement between the Engineering Experiment Station of the University of Illinois, the State Geological Survey, and the United States Bureau of Mines. The reports of this coöperative investigation are issued in the form of bulletins by the Engineering Experiment Station, the State Geological Survey and the United States Bureau of Mines. For bulletins issued by the Engineering Experiment Station, address Engineering Experiment Station, Urbana, Illinois; for those issued by the State Geological Survey, address State Geological Survey, Urbana, Illinois; and for those issued by the United States Bureau of Mines, address the Director, United States Bureau of Mines, Washington, D. C.

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A STUDY OF COAL MINE HAULAGE IN ILLINOIS

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A STUDY OF COAL MINE HAULAGE IN ILLINOIS

I. Introduction

1. *Scope of Present Discussion.*—Very few, even of those connected with the coal mining industry, appreciate fully the importance and extent of the underground haulage problems in a modern coal mine. The transition from mule haulage to modern electric locomotive haulage has been so rapid that there has not been time for most of those engaged in operating mines to study haulage practice in detail as has been done in connection with surface railroads; for example, in the tabulation of the ton-miles performance per locomotive per day, and similar statistical information. When one considers that at a large mine in Illinois 6000 or more tons of coal per day are hoisted in 5-ton capacity cars and that 1200 or more cars per day, or 150 per hour, must therefore be gathered from different parts of the mine, concentrated at the shaft bottom, loaded upon the cage over only two tracks, hoisted to the surface, lowered to the shaft bottom, and again distributed to remote parts of the mine, one realizes that here is a condition demanding thought and study if the most effective operation is to be secured from expensive equipment.

The coal mines of Illinois afford an unusually favorable opportunity for a study of the haulage problem, for not only are they the largest in point of output of any coal mines in the world,* but there are few if any other coal fields of equal size where the operating conditions are so uniform. Beginning with primitive methods and equipment, the coal industry in the state has grown steadily until Illinois ranks third in coal production in the United States. The owners of the mines have not only kept pace with those of other regions, but they have in many instances been pioneers in installing improved equipment such as car lifts, self-dumping cages, and improvements about the shaft bottom.

An effort has been made in the present bulletin to trace briefly the development and history of mine haulage in general and in Illinois in particular. Mine haulage practice and costs have been considered under the three natural phases of shaft-bottom activities, main-line haulage, and gathering; while particular attention is called to Tables 4, 5, 7, and 8 which give the results of detailed studies in a number of the large producing mines of the state, that is, those with 3000 to 6000 tons per day output. These mines were studied in considerable detail and the results as presented in tables and graphs show that there is a wide diversity in the results obtained in mines of like capacity, with similar equipment, and operating under similar natural conditions. The tables suggest that a more detailed study of operating conditions in a number of mines of the state would produce a greater efficiency in operation even with the equipment already installed. This applies not only to the mechanical results obtained, as measured by performance in ton-miles etc., but also to the variations in costs for mines similarly equipped.

Approximately one-seventh of all coal mining employees are engaged in underground haulage duties, classified under 46 different occupations on the account books of different companies. In the present discussion of the subject, however, haulage is assumed to stop when the car is placed on the cage to be hoisted, thus excluding hoisting, although in the matter of cost it is not always possible to separate the hoisting cost from the haulage. In such cases, however, the hoisting cost is relatively small and does not materially affect the total haulage cost. Owing to the diverse accounting systems employed by different companies it is difficult to obtain comparative data for different mines, although the owners of the mines and the local superintendents have been most obliging in extending privileges for investigating haulage operations and in supplying information relative to operating costs.

Every study of an industrial problem should include a consideration of the accidents connected with the industry; therefore some discussion of accidents in mine haulage, based upon the statistics given in the Coal Reports of the Illinois Department of Mines and Minerals, is included in this bulletin. An analysis of these statistics has been made in the effort to show the relation between coal production, number of employees, and the number of fatalities due to haulage operations among various classes of mine employees.

2. *Acknowledgments.*—This bulletin is the outgrowth of a study of Mine Haulage undertaken as a research problem under the direction of the Engineering Experiment Station of the University of Illinois by A. C. CALLEN* while Associate in Mining Engineering at the

* Now Professor of Mining Engineering, University of West Virginia.

University. He prepared much of the historical material and some of the statistics for accidents that occurred prior to 1917.

Upon the resignation of Mr. Callen the study was continued under the Coöperative Coal Mining Agreement between the Engineering Experiment Station, University of Illinois, the United States Bureau of Mines, and the Illinois State Geological Survey.

The field studies of haulage operation were carried on mainly by J. R. Fleming, who, together with A. J. Hoskin, prepared the tables and graphs giving the results of these field studies. Mr. Fleming also supplemented the studies of accidents made by Mr. Callen. Final arrangement, checking, and editing of the manuscript was done by A. J. Hoskin and H. H. Stoek.

The authors gratefully acknowledge the hearty coöperation of the owners and operating officials of many of the mines in the state in giving assistance, not only through replies to requests for information by mail, but also in carrying on the studies in the mines and in permitting free access to the books of the companies in order to obtain costs of operation. They are also indebted to J. J. Rutledge, Superintendent of the Urbana Station of the United States Bureau of Mines, and F. W. DeWolf, Chief of the Illinois Geological Survey, for suggestions during the progress of the investigation, and for their careful review of the manuscript.

II. Evolution of Mine Haulage

3. *Early Practices.*—The primitive method of transporting material from underground mine workings was for men to carry it in some form of container, as a tray.* Similar methods are still used in a few places where the natural conditions of the mineral deposit make them necessary, or where they are economically possible.† The introduction of wooden sleds was an improvement over carrying. Such sleds, or baskets, provided with runners and usually drawn by boys, were extensively used in Great Britain in early coal mining, and are still used in thin seams where the expense of taking down the roof to obtain necessary head-room for cars is prohibitive.‡

The introduction of wheeled vehicles was the next advance step. By using a wheelbarrow heavier loads could be moved with much less exertion than by carrying, especially if a plank road was used instead of the natural mine floor. Although wheelbarrows are still used in many ore mines, they are seldom found in coal mines.

The four-wheeled truck or car soon replaced the wheelbarrow for general use. At first, wicker baskets or wooden tubs were loaded at the face and carried to the haulage road, but soon cars or "waggons" were made of such a size that they could be taken to the face. The "buggies," still used in Kansas longwall mining for transporting the coal from the advancing face to the road-head where it is transferred to the regular mine cars, are illustrated in Fig. 1.§ This buggy is run along the longwall face on eight-pound steel rails. The track is made up in eight-foot sections with a curve section for the road-head, so that it can be easily handled.

In England the term "tub" is still used for a mine car though very few real tubs are used. Pushing cars by hand is known as "putting" in England and as "tramming" or "hand tramming" in the United States.

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* Agricola, "De Re Metallica." Book VI, p. 56, translated by H. Hoover.
A. Pliny (XXXIII, 21).

† Tonge, J. "Principles and Practice of Coal Mining," p. 162, London, 1906.

‡ Hughes, H. W. "A Text Book of Coal Mining," p. 224, London, 1904.

§ This photograph is furnished through the courtesy of C. N. Fish, general manager of the Home Riverside Coal Mines Co., Leavenworth, Kansas.

FIG. 1. WHEEL BUGGY IN KANSAS COAL MINE

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"Cast-iron tram plates were introduced in English mines in 1767 and were in turn succeeded by wrought iron rails and steel rails."*

The modern coal-mine car bears little resemblance to the early "tubs." Samuel Dean, an English mining engineer who has written extensively on the coal mines of the United States, attributes the larger output per man in the United States to the larger capacity of cars used.†

4. *Hand Tramming.*—Hand tramming, by which is meant the manual pushing of cars or trucks, was among the earliest systems of transporting mined material. At present it is used mainly in coal mines of small capacity where the working face is not far from the shaft bottom or drift opening, or in places where the height of entry is too small for animal or mechanical haulage. In some coal mines miners push the empty cars from a distributing parting to the working face; in others, though less frequently, loaded cars are pushed from the face to the parting where they are formed into trips for animal or mechanical haulage. This system requires suitable grades and cars of such capacity that they can be moved readily and easily kept under control. The amount of hand tramming in unionized mines is generally stipulated in the agreement between the miner and the operator.

5. *Animal Haulage.*—Following the enactment of a law prohibiting the employment of women or of children under 10 years of age, Shetland ponies were introduced in English mines in the year 1843, as substitutes for the putters employed in conveying the coal from the working face to the main roads.‡ Where coal seams were thicker, horses were employed and in England they are still the favorite animals for underground labor. In the United States mules are generally preferred to horses as they are quicker and more sure-footed. Dogs have been used in small Illinois mines for hauling coal. In one Ohio mine they are said to have been used for over thirty years. Overman, in his "Metallurgy" published in 1852, says that the dog-cart was at that time in general use in coal mines of the western United States and was a most convenient vehicle for

* Foster & Cox, "Ore and Stone Mining," p. 373.

† Trans. Inst. Min. E. Vol. 50, p. 179.

‡ R. L. Galloway, "Annals of Coal Mining." Vol. 2, p. 344.

handling coal underground.* Oxen have been used for coal haulage to a very limited extent.

Mules, horses, and ponies are still widely used in the mines of the United States. Although sometimes employed in main haulage their chief use is in gathering cars on short hauls, that is, in taking the loaded cars from the working face to a parting where the cars are made into trips for transportation by mechanical means.

6. *Mechanical Haulage.*—The principal forms of mechanical haulage now in use are rope haulage and locomotive haulage.

Rope Haulage

Rope Haulage may be divided into four systems: Engine Planes, Gravity Planes, Endless Rope, and Main and Tail Rope.

An Engine Plane is an inclined plane up which a load is drawn by an engine or motor. Such a plane may work "in balance," the empty cars descending while the loads are coming up, thus partially balancing the system and reducing the load on the engine; or the system may work "unbalanced," in which case the engine simply draws the loaded cars up the plane while the empty cars pull the rope down again.

The earliest adoption of mechanical haulage underground was about 1812 or 1813, when George Stephenson so altered an underground engine at Killingworth colliery, England, as to make it haul the coal up an inclined plane to the shaft.† Chains were originally used to haul the cars up. About the year 1841 "the haulage of coal by ropes was greatly facilitated by the introduction of light, round iron wire ropes."‡

A Gravity Plane is one of such inclination that the loaded cars going down the plane pull the empty cars up, the inclination being usually over 20 per cent. Such planes are used where the coal must be transferred to a lower level; for example, in mountainous regions where the mine openings are located at elevations above the tipple, and inside mines where the coal beds are steeply inclined.

An Endless Rope haulage system has an endless rope that is operated continuously by a haulage engine at a speed of usually two to four miles per hour. The cars are attached to the rope, either

* Col. Eng. Vol. 20, p. 684.

† Galloway, R. L. "Annals of Coal Mining." Vol. 2, p. 340.

‡ Galloway, R. L. "Annals of Coal Mining." Vol. 2, p. 344.

singly or in groups, by grips or clamps which can be easily fastened to or unfastened from the rope. Two tracks are required, one for the loads and the other for the empties. The system is used mainly on short hauls and on steep pitches such as slope openings.

In the Main and Tail Rope system a trip of loaded cars is pulled by the main rope, a tail rope being fastened to the rear end of the trip and dragged after it. At the destination the ropes are uncoupled from the cars and the tail rope is fastened to the front end of the empty trip while the main rope is fastened to the rear end. The trip of empty cars is then pulled in by the tail rope and the main rope dragged after the trip. The speed of operation is usually 6 to 10 miles per hour. The system is used mainly on a haulage road having undulating grades.

Rope haulage is said to have been introduced in the United States about 1870.*

Locomotive Haulage

The different types of mine locomotives that have been used are steam locomotives, compressed-air locomotives, gasoline locomotives, and electrical locomotives.

The exact date of the first use of steam locomotives in connection with underground mining in the United States is not definitely known, but according to E. B. Wilson it was prior to 1870.†

On account of the smoke and other products of combustion, such locomotives should be restricted in their use to the return air-ways. At one time they were extensively used in the anthracite region of Pennsylvania and from 1883 to 1895 in the Pocahontas region of West Virginia, but they have never been used in Illinois. There are still a few steam locomotives used in the Pocahontas district at three or four of the small mines where the tonnage remaining to be mined does not warrant the expense of a change to electric haulage.‡

From 1875 to 1895 may be called the experimental period of the compressed-air locomotive. Ten or twelve were built during this twenty-year period and were installed by operators who desired a haulage system that would eliminate fire risk, be free from the dangers of electric wires, and be comparatively safe in a gassy

* Mines and Minerals. Vol. 31, p. 71.
† Mines and Minerals. Vol. 31, p. 71.
‡ Private communication, Lincoln, J. J.

mine. In construction compressed-air locomotives differ from steam engines mainly in having, instead of a steam boiler, a large storage tank which can be charged with air at a pressure of from 600 to 1000 pounds per square inch, and a reducing valve set to supply air to the cylinders at a constant pressure of 150 pounds. From 1895 to 1908 great improvements in design and manufacture were made, and several hundred locomotives were furnished to mining companies.

In 1908 the first two-stage compressed-air locomotive was put upon the market and, in the three years succeeding, over 100 were built.*

According to the H. K. Porter Company of Pittsburgh, Pennsylvania, there were in 1921 no compressed-air locomotives operating in the coal mines of the Mississippi Valley, but in the mines of Western Pennsylvania and West Virginia the total number was about 150.

There are two great advantages of compressed-air locomotives: first, they are comparatively safe for use in gassy mines, and second, they require neither trolley wire nor rail bonding.

On the other hand they are bulky, and their radius of operation is limited by their air-storage capacity. However, in mines having ample cross-section of the entries this is not serious as tanks of a capacity sufficient for a run of several miles may be used.

The advantages of a locomotive carrying its own source of power, such as a gasoline locomotive, are obvious. It was but natural that an attempt should be made to use the internal-combustion engine for mining service and, indeed, before the automobile had advanced much beyond the experimental stage, a gasoline locomotive was tried out for hauling coal.

Probably the first gasoline mining locomotive made in this country was furnished in 1898 by W. F. Prouty of Philadelphia, Pennsylvania, and Newark, New Jersey, to the St. Bernard Mining Co. for use in the No. 9 mine at Earlington, Kentucky.† This locomotive was in service for a year, but was never able to pull a full trip of loaded cars and was finally scrapped.

It is likely that gasoline locomotives had been in use in Europe for some years previous to this date. In 1899, in describing the explosion-proof gasoline motors used in the coal mines of Belgium,

* Mines and Minerals. Vol. 31, p. 365.

† Coal Age. Vol. 5. p 9.

M. J. Kersten said, "It is only quite lately that a locomotive working with petroleum has been used in fiery mines,"* the presumption being that they had been used for several years in non-gassy mines.

The first gasoline locomotive used in Illinois was probably the second successful one in this country. It was built by the Sangamon Coal Co. and put in its mine at Springfield, 1904. This crude machine pulled a trip of seven to nine mine cars, each weighing, when loaded, 4000 pounds. A few locomotives of this type were built in Chicago and in St. Louis about 1905 or 1906, but the St. Louis locomotives were returned to the manufacturers as they cost more for repairs than the value of the coal they hauled. A few gasoline mine locomotives were made by Fairbanks, Morse & Co. in 1907.†

In 1909 gasoline locomotives were introduced into the lead mines of southeastern Missouri where the Desloges Consolidated Co., on account of its very excellent ventilation, was able to use them with success.‡ The George D. Whitcomb Co. shipped one to the Kolb Coal Co. of Mascoutah, Illinois, in 1909. This locomotive gave such satisfaction that several more were ordered by this company. In 1910 it was stated§ that there were three hundred of these locomotives in use in all parts of the world. In 1915 about that number were in use in the United States.

Although gasoline locomotives have the great advantage of flexibility and cheapness of installation, their use underground has been restricted because of the possible danger from the exhaust gases and from the extra mechanical attention necessary to keep them in operating condition. Their use underground is steadily decreasing; storage-battery locomotives are replacing them to a very great extent. Gasoline locomotives are restricted in their use to main-line haulage and in this to return air-ways only.

In 1914 the United States Bureau of Mines conducted an investigation into the vitiation of mine air resulting from the use of gasoline engines. According to the conclusions of the Bureau,¶ the ventilating current—in order to safely dilute the obnoxious carbon monoxide exhausted from a gasoline locomotive—should be increased to the extent

* Eng. and Min. Jour. Vol. 68, p. 724.

† Illinois Coal Mining Investigations. Bul. 13, p. 179.

‡ Eng. and Min. Jour. Vol. 84, p. 346.

§ Mines and Minerals. Vol. 31, p 30.

¶ Hood and Kudlich, U. S. Bureau of Mines. Bul. 74, Gasoline Mine Locomotives in Relation to Safety and Health, p. 7.

of from 2610 to 35 140 cubic feet per minute, this additional volume of air depending upon the size of the engine and the thoroughness of the carburation. These figures are based upon the dilution of the poisonous gas to one part in 1000 parts of air, this quality of atmosphere being safe for men and animals to breathe for "short and infrequent intervals" only. For continued conditions the dilution should be to not more than one part of the engine's exhaust in 2000 parts of fresh air. It will be seen that this feature of gasoline locomotives is a serious objection to their use underground even upon return air-ways. In the attempt to restrict the pollution of the mine air experiments have been made with passing the engine exhaust through chemical solutions but the results were unsatisfactory.

The first electric locomotive using current from a dynamo was built by Siemens and Halske in Germany, and, at the Berlin Trade Exhibition in 1879,* was operated upon a circular track about 1500 feet long. The introduction of electric locomotives into mining service followed almost immediately, and in 1882 the first electric mine locomotive was installed in the royal coal mines at Zaukerode, Saxony.† This system of haulage was adopted by the Consolidated Paulus and Hohenzollern Collieries at Beuthen in 1883, and at New Stassfurt in 1884. The locomotives were all built by the Siemens and Halske Co. On July 26, 1887, the Lykens Valley Coal Co. put the first electric mining locomotive in this country into service at the Short Mountain Colliery at Lykens, Pennsylvania.‡ This locomotive had a 30-horsepower motor wound for 400 volts direct current. The conductor was a 25-pound iron rail mounted along one side of the entry, current being taken off through four contact wheels. The motor and running gear weighed 1500 pounds, but the machine was weighted with scrap iron up to 7000 pounds. (See Fig. 2.) It was built by the Union Electric Co. of Philadelphia, Pennsylvania. This installation was the first of any considerable size in the world. The Siemens and Halske locomotives weighed only two tons each and hauled a train load of about 10 tons, while the Lykens Valley "Pioneer" hauled a load of 150 tons at a speed of six miles per hour over a road about 6300 feet long. It was still in service in 1915. In

* Sprague, F. J., Elect. Ry., p. 3. Int. Eng. Cong. 1904, p. 3.

† Electric Locomotives in German Mines. Karl Eilers, Trans. A. I. M. E. Vol. 20, p. 356.

‡ Col. Engr. Vol. 8, p. 43. Also Thesis of H. H. Stoek.

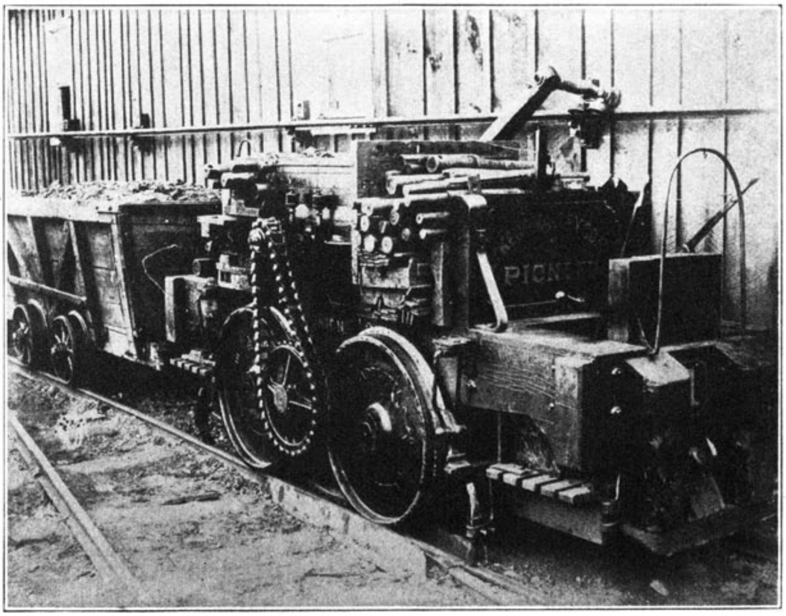

FIG. 2. FIRST ELECTRIC MINE LOCOMOTIVE IN UNITED STATES

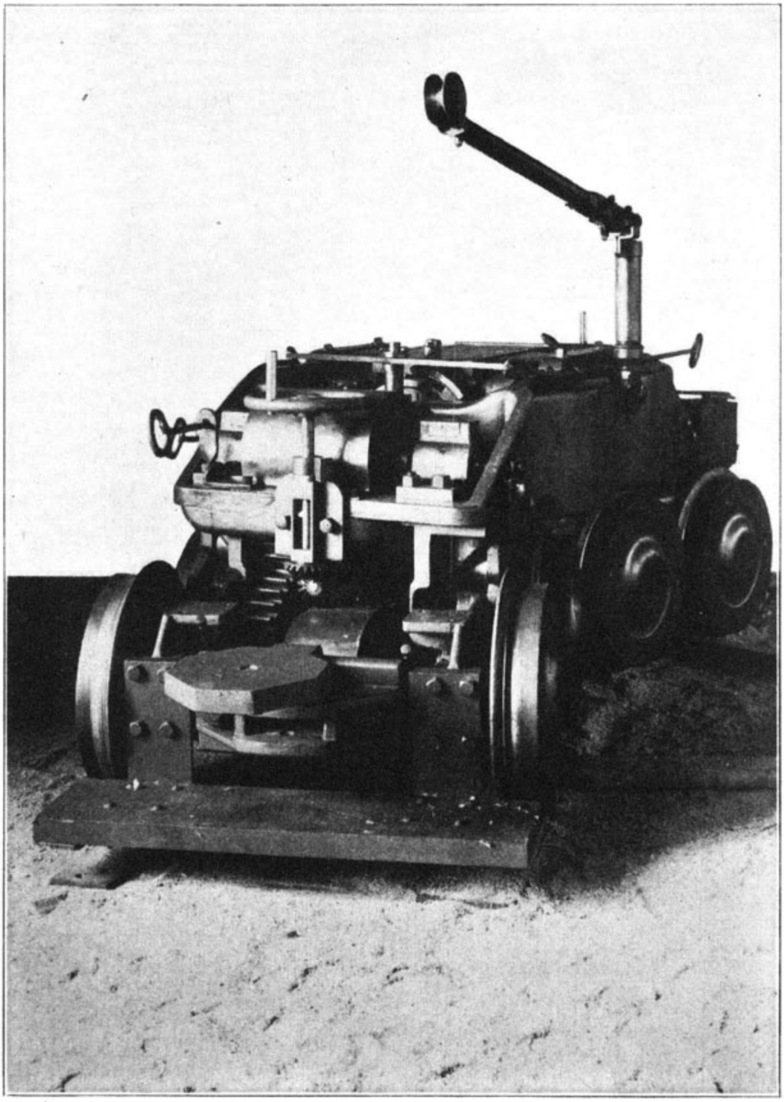

FIG. 3. FIRST ELECTRIC LOCOMOTIVE IN ILLINOIS MINES

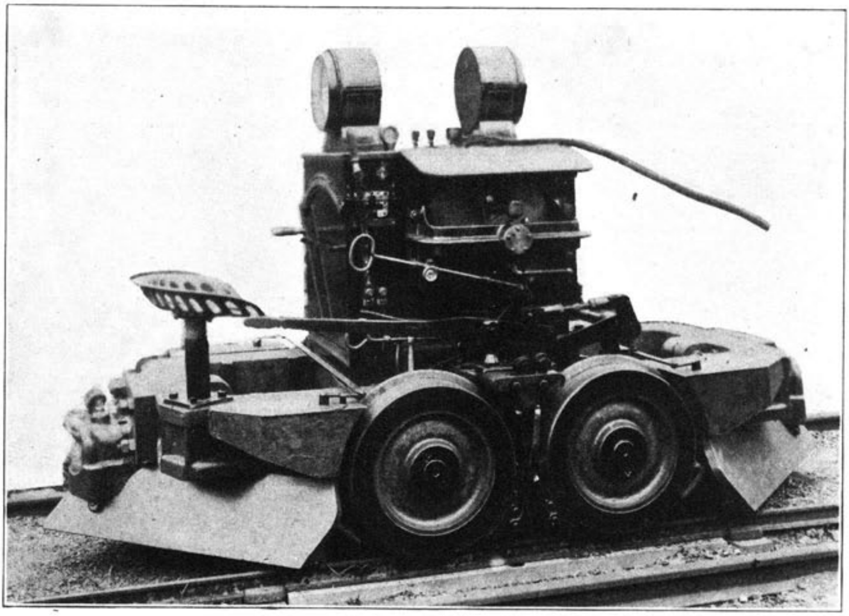

FIG. 4. EARLY TYPE LOCOMOTIVE USED AT CENTRALIA, ILLINOIS, IN 1899

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1888 the Jeffrey Manufacturing Co. built the first electric locomotive used in a bituminous coal mine in the United States. This installation was in the mines of the Upson Coal Mining Co., Shawnee, Ohio. Instead of a wire or rail as a conductor two parallel 1-inch galvanized iron pipes were used. The rails were not bonded, as one of the pipes was used for the return circuit.

The first electric mine locomotive installed in the State of Illinois was placed in the No. 3 mine of the Chicago, Wilmington & Vermilion Coal Company at Streator in 1888. This locomotive, Fig. 3, was designed by Elmer A. Sperry of the Sperry Electric Mining Machine Company of Chicago, (the predecessor of the Goodman Manufacturing Company), and was built by that company. This was an experimental machine and was provided with eight driving wheels and a motor of about 30 horsepower. The total weight of the machine was about six tons. Referring to this first electric mine locomotive in Illinois, C. A. Pratt, Chief Engineer of the Goodman Manufacturing Company, says:* "It was in operation several months and was then replaced by a locomotive of somewhat modified design and of greater weight and horsepower. The locomotive which replaced it had eight driving wheels distributed on two bogey trucks. These wheels were about 20 inches in diameter and the locomotive was designed to turn on a curve of 8 or 9 feet radius. The locomotive weighed about 8 tons and was driven by one 60-horsepower motor, the armature of which was geared to all of the eight wheels. A second locomotive of the same description was put into the same mine some months later and these two locomotives were operated for many years." As far as can be learned this installation at Streator was the only really successful one for several years, though some locomotives had been used experimentally at other mines. No further introduction of electric haulage was made in Illinois until 1899 when the Jeffrey Manufacturing Co. shipped an 8-ton locomotive, Fig. 4, to the Centralia Mining and Manufacturing Company of Centralia, Illinois.

The years 1899 to 1904 may be called the introductory period. The increase in installations was slow but steady so that by the close of this period each of the important mining districts in the state had at least one mine in which electric locomotives were being used with success.

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* Private communication.

The introduction of the electric locomotive and its successful operation in main haulage led to attempts to extend this system to gathering service. In early practice miners pushed their loaded cars to the room necks whence the cars could be hauled to main partings by trolley locomotives. When rooms were driven to the rise this practice occasionally involved accidents from runaway cars. A locomotive was therefore needed to do such gathering safely, but of a type that required no trolley extensions into the rooms. In response to this need the cable locomotive was designed. Briefly defined, this locomotive is one that can not only operate as a trolley locomotive but also travel on track not equipped with trolley wire by taking its power through a long flexible conductor or cable that it carries mounted on a drum or reel.

Probably the first successful cable locomotive was constructed in 1900 in the shops of the Pocahontas Consolidated Collieries Co. at Pocahontas, Virginia.* For several years previous this company had been trying to develop a storage-battery locomotive but without success. So, in 1900, they mounted on one of these old locomotive frames, with the motor, a vertical cable reel, thus making a very good gathering locomotive known later as the "Wampus" on account of its peculiar appearance. Since 1900 all electric locomotive manufacturers have constructed gathering locomotives, the designs being generally similar. The cable through which the locomotive receives its power when away from the trolley wire is wound either on a reel placed horizontally on top of the locomotive, or on a drum placed at one end. The reel or drum is driven by an independent motor, by a spring device, or by a chain and sprocket wheels from the axle.

Where the rooms dip rather steeply towards the face it may be impossible or undesirable for the locomotive to go to the face for the cars. In such instances the "crab" locomotive has been used with success. This locomotive is equipped with a drum on which a steel cable is wound and which is usually driven by a separate motor, thus in reality adding to the locomotive a small hoisting engine for the purpose of pulling cars out of steeply pitching places while the locomotive remains on the entry. Under some conditions a gathering locomotive is equipped with this "crab" device in addition to the cable attachment.

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* Mines and Minerals. Vol. 30, p. 13.

The rack-rail locomotive was devised for electric haulage on heavy grades. Its hauling capacity is not limited to the adhesion between the wheels and rails. Instead of driving the wheels the motor is geared to a sprocket wheel beneath the locomotive, the teeth meshing with a rack-rail laid between the main rails. The locomotive is therefore really geared to the track and can haul large loads on steep grades, provided the strength of the parts and the power of the motor are sufficient. Rack-rail locomotives were first brought out by the Morgan-Gardner Co. in 1899. They are used in mines where the grades are prohibitive to ordinary electric haulage. In some cases no trolley wire is used, the rack-rail acting as a conductor for the current. In other cases a trolley wire is used on the ordinary haulage roads, the rack-rail being used only on occasional grades.

From the time that electric haulage was first introduced in mines it has been the desire of engineers to find some way of dispensing with the trolley wire and the bonding of the rails; first, from a desire to save the outlay required by such an installation, and second, because of the danger from contact with the wire, and from explosions caused by sparking of trolleys and wheels in gassy mines. As regards the latter danger the United States Bureau of Mines at the Pittsburgh Testing Station is prepared to test locomotives in a gas chamber and, if they can comply with requirements, to list them as permissible for use in gaseous atmospheres. It is doubtful, however, if any trolley or reel locomotive can meet these requirements. This condition, therefore, led to the introduction of the storage-battery locomotive, which, while it does not eliminate the danger from switch and motor sparks, at least dispenses with the trolley wire.

The commercial development of the storage battery began at about the same time as did that of the electric railway, for it was not until 1880 that Brush and Faure, working independently, simultaneously produced the pasted plate for storage batteries, resulting in lighter and cheaper cells. Naturally the storage battery was looked to as the solution of the problem of dispensing with trolley wires or other naked conductors. The early development of such locomotives took place in England and in Germany, American engineers being slow to take up the subject. In 1886 the first storage-battery locomotive was tried in the mine of the Trafalgar Colliery Co.* Indicative of the

* Eng. and Min. Jour. Vol. 42, p. 98.

slow development of the early installations was the statement made in 1895 that storage-battery locomotives had then reached the experimental stage only.* Probably the first successful use of a storage-battery locomotive in this country was at the mines of the Southwest Virginia Improvement Co. in the Pocahontas region of West Virginia.† The Baldwin-Westinghouse Co. built this locomotive in 1899 and it proved so successful that the company ordered six more. For several years prior to this the Pocahontas Consolidated Collieries Co. at Pocahontas, Virginia, had endeavored to develop a storage-battery haulage locomotive, three machines actually having been built which were, however, only "more or less effective."

About 1900 the Jeffrey Manufacturing Co. shipped its first storage-battery locomotive. During the following ten years there were several locomotives of this type put into service but, on the whole, development was slow. Beginning with 1911 these locomotives began to attract a great deal of attention. Storage batteries had been improved both in design and construction. The Edison alkaline battery with a steel jar had been placed on the market and had given excellent service. Mining men did not need to be convinced of the advantages in the use of storage-battery locomotives, but they were extremely dubious about the ability of a battery to stand up under the severe conditions of mining service. In some storage-battery locomotives, particularly of the earlier types, batteries were too small and motors were of too low capacity for the weight of the locomotive. Whereas in main-haulage locomotives of the trolley type motors of approximately 10 to 12 horsepower per ton of weight are used, in some storage-battery locomotives the motor capacity has been as low as one horsepower per ton of weight. This radical difference restricts the continuous performance of the storage-battery locomotive for heavy work and necessitates extra care to maintain the batteries in proper working condition. This places storage-battery locomotives at a disadvantage as compared with trolley and cable-reel locomotives. Recently storage-battery locomotive manufacturers have shown a tendency to install larger motors than formerly.

These locomotives are fitted with motors that are built to withstand heavy overloads. Although their normal ratings may be relatively low they will stand without injury overloads of 300 to 400

* Col. Engr. Vol. 16, p. 32.

† Mines and Minerals. Vol. 30, p. 13.

per cent if not too long sustained. For instance, a certain four-ton machine is rated at 80 volts and 60 amperes when running at about 1050 revolutions per minute, this being equivalent to slightly more than six horse power.* However, it is not unusual for this machine on short hauls to consume 300 to 350 amperes. This practice is based upon the following general considerations: These light-weight storage-battery locomotives are used to do both gathering and main haulage. During the work of gathering the duty is light, perhaps 75 to 80 per cent of the working time being spent in hauling one car at a time to and from rooms. When a few cars have been collected in an entry they are hauled to a parting where a train is made up and the locomotive then hauls this train to the shaft bottom. Assuming that the average distance from parting to bottom is 2000 feet and that a speed of four miles per hour is maintained, the run will require less than six minutes. For such a short period these motors will easily withstand the overloads, which may be six or seven times the normal ratings.

As regards electric mining locomotives in general, in earlier practice, when the hauls were short, seven and eight horsepower per ton of locomotive weight was commonly used; that is, from 70 to 80 horsepower on a 10-ton locomotive traveling at a speed of six miles per hour. As the requirements became more severe it was found that motors of such horsepower overheated, wherefore motor capacities were increased to a minimum of 10 horsepower per ton in general mining practice. As the loads to be hauled by the main-haulage locomotives increased, manufacturers increased the motor capacities to not less than 12 horsepower per ton for locomotives above eight tons rating. For long hauls it is now not uncommon to use still greater horsepower where the circumstances will permit. Under severe conditions mine locomotives may be required to develop in excess of 15 horsepower per ton, and such requirements are fulfilled successfully by applying forced ventilation to the motors.

The chief demand of mining men has been for increased locomotive capacity without increase in size. In discussing compactness of design G. M. Eaton, chief engineer of the Westinghouse Electric and Manufacturing Company, cites an electric mining locomotive built in 1896 that had a ratio of volume (cubic feet) to horsepower of 3.88,

* This is on the basis of 55-deg. temp. rise in 4 hr., and not on the A. I. E. E. restriction of 75 deg. in 1 hr.

while a more modern locomotive of the same motor capacity has a ratio of 1.54.*

Manufacturers have experimented to secure equal distribution of weight on the driving wheels; to prevent the slippage of one set of the wheels, when only one motor is used, by connecting the front and rear axles; to determine the best position of the drawbar to assure the most advantageous line of pull; to increase the effective drawbar-pull by increasing the weight of the locomotive; to so increase the number of driving wheels as to distribute the weight and reduce the load on each wheel; to make possible the use of tandem locomotives or of trailers upon which is carried all excessive weight (particularly that due to the use of the storage battery) so that the driving wheels will carry only the weight desired for the required pull; to introduce steel-tired wheels instead of cast-iron wheels in order to secure greater adhesion to the rail; to decrease the friction in the locomotive by the use of special bearings and improved methods of lubrication; and to mount independent motors in a storage-battery locomotive—one for trolley current, the other for battery current.

Improvements and changes in the design of electric locomotives have been made principally as follows:

(a) Details of construction, both electrical and mechanical, have been modified to better adapt the locomotives to severe mine service.

(b) Compactness has been sought to permit use of locomotives in restricted quarters.

(c) Increased capacity and endurance have been secured for the electrical equipment.

(d) Greater flexibility of movement has been obtained through the use of cables and storage batteries.

Among the modifications of details of mechanical construction may be mentioned the change from ordinary brass bearings to ball bearings for armatures; the use of heat-treated or hardened motor pinions; the making of all working parts much heavier to take care of the increased duties imposed upon them; and the making of such working parts more accessible and more readily detachable.

Locomotive frames were originally made of cast iron. These did very well unless collisions occurred, when repairs were difficult.

* Development of Electric Mine Locomotive. Proc. A. I. E. E., April, 1914.

Later, cast steel came into use for frames and to a certain extent is used for parts of the frames by some builders today, although rolled-plate side-frames are more common. Rolled steel is more uniform than cast steel and it is less likely to contain blow-holes. Some builders have given special attention to the bracing of the frame at the corners to resist blows from collisions or derailment. One company equips its locomotives with an auxiliary buffer and interposes springs between it and the main locomotive frame to take up the shocks of collision, coupling, and starting. This construction results in a saving on car hitchings and bumpers and is of assistance in starting trips.

In the early locomotives axles were too weak, journal boxes were too short for the weight, journal springs were not sufficiently flexible to meet the conditions of mine track, motor suspensions were often too rigid to allow the wheels and axles to follow the track, and brake-riggings had springs that reduced the effectiveness of the brakes. Many early locomotives were made with a chain drive between the axles, but this method of driving has been abandoned by several manufacturers whose locomotives now have either a single motor geared to both axles, or two motors, one for each axle. One manufacturer, however, continues the chain drive, with good arguments for its superiority over direct gearing.

Amongst the improvements in electrical details may be noticed first the use of commutating poles on the motor to prevent sparking, and second, the thorough enclosing of the electrical parts, these changes at once reducing the danger of fire or explosion and increasing the life of the parts.

In many instances field-windings have been changed from cotton-covered wire to strap copper insulated between layers or turns with sheet asbestos and the whole wrapped with oiled linen, asbestos tape, or other fireproof insulation, baked with varnish. Formerly the fields would deteriorate from heating; now life is indefinitely prolonged. When necessary it is a comparatively simple matter to repair the strap coils without the loss of any copper, whereas, with the wire-wound fields repairs to defective or damaged insulation often required the purchase of new copper wire or new material throughout. The armature coils were generally wire frequently of two or more turns per coil, but today they are largely made of bar or strap copper of only one turn per coil. The repairing of this type of coil is very much simpler and the copper is usually salvaged, whereas with the old type a complete replacement of the damaged parts was generally necessary. The material used in insulation is of much better quality than that used heretofore, securing increased life of the coil. The single-turn coil results in better commutation and less sparking at the brushes than was possible with the older construction.

The improvement in locomotive controllers has been marked. Those now used are of the straight type without any auxiliary devices. The size and capacity of the blow-out coils have been greatly increased and, in the best designs, strap copper with fire-proof insulation is used.

On storage-battery locomotives it is considered best practice to have all switches in an enclosed compartment so that they can not be thrown when the locomotive is operated under gassy conditions. No attempt has been made to enclose the storage batteries themselves in explosion-proof cases, as circuits are not broken while the batteries are operating, and there must be ample ventilation about the batteries to carry away the gas generated therein.

An effort has been made to standardize practice in mine haulage through a committee of the American Mining Congress for the Standardization of Underground Transportation Equipment. Although the subjects that have been investigated by this committee—such as track gauge, minimum track curvature for rooms, wheel-base for mine cars, types of couplers, and overall dimensions of mine cars—apply primarily to track and mine-car construction, any standards adopted will affect locomotive design. The rating of mine-locomotive motors is generally governed by the rules of the American Institute of Electrical Engineers for railway-type motors. The rated horsepower delivered for one hour should not heat the windings more than 75 degrees C. above the surrounding air, Standardization Rule No. 415 being as follows:

> "The nominal rating of a railway motor shall be the mechanical output at the car or locomotive axle, measured in kilowatts, which causes a rise of temperature above the surrounding air, by thermometer, not exceeding 90 degrees C. at any other normally accessible part after 1 hour continuous run at its rated voltage (and frequency in the case of an alternating-current motor) on a stand with the motor covers arranged to secure maximum ventilation without external blower. The rise in temperature as measured by resistance, shall not exceed 100 degrees C."

The Electric Power Club has the following standard rule specifically applying to mine locomotives:

"Mine locomotive motors shall be given nominal ratings which shall be the horsepower output at the armature shaft, excluding gear and other transmission losses, which the motor will develop for one hour under normal rated conditions on a stand test with covers removed and natural ventilation, without exceeding the temperature rises guaranteed."

In order that the motor shall have good continuous operating capacity, in proportion to its capacity on the hour rating, it is necessary to have a liberal radiating surface in addition to the usual requirements of ample area of conductors and commutator.

The manufacturers usually guarantee a certain starting drawbar-pull on clean, dry rails, and also running drawbar-pull at specified speeds.

7. *Mine Haulage in Illinois.*—Most of the large producing mines in Illinois are being operated in seams of coal which are usually over 5 feet in thickness, thus permitting the use of cars that are larger than the average used in the United States. The largest car in use holds about 5 tons and the average about 3 tons. With the exception of occasional heavy local grades the coal seams are nearly level. The floor is fire clay and affords a good road-bed. These conditions permit a systematic arrangement of haulage ways and favorable and efficient haulage. Because of these favorable natural conditions and because the more modern mines are all designed for large tonnages, large capital investments have been made, with the result that the more modern Illinois mines are exceptionally well equipped. Cars of the capacity noted above require a good track; therefore, in most of the mines developed during the past ten years 40-pound rails have been used on the main entries and 20-pound rails in the rooms. In the more recent operations 45- to 60-pound rails have been used on the main roads and 25- to 35-pound rails in the rooms. Most of the newer mines have adopted a track gauge of 42 inches.

Statistics for 1920 showed 345 shaft mines, 12 slope mines and 10 drift mines. The average depth of shaft was 225 ft. while the average slope length was 772 ft. The production from the different kinds of mines was: shaft mines, 69 004 807 tons; slope mines, 2 339 167 tons; drift mines, 717 096 tons. During the same year strip mines produced 367 009 tons or a little more than one-half of one per cent of the total production in the state.

Data from Illinois Coal Reports for the period 1899 to 1921

TABLE 1

KINDS OF HAULAGE IN ILLINOIS SHIPPING MINES

Used on Main Haulage System

Year	Locomotives*			Rope		Mules			Hand Tramming	
	No. Mines	Tonnage	No. Locomotives	No. Mines	Tonnage	No. Mines	Tonnage	No. Mules	No. Mines	Tonnage
1899	3	591 274	....	19	1 849 474	407	20 301 405	....	456	571 927
1900	7	1 331 579	....	27	2 424 278	512	20 410 169	....	374	987 570
1901	12	2 759 872	....	21	2 740 616	545	20 391 023	....	341	743 808
1902	13	3 043 497	....	15	2 626 182	289	22 050 515	....	7	30 329
1903	16	3 947 601	....	26	3 518 122	298	25 425 799	....	10	60 825
1904	22	4 779 822	....	28	4 287 836	302	24 829 705	....	18	107 426
1905	33	6 984 054	....	18	2 064 132	318	24 327 719	....	14	84 186
1906	46	8 736 686	....	30	2 789 640	324	24 371 623	....	12	75 547
1907	75	16 542 575	129	25	2 864 241	303	26 689 533	....	5	46 865
1908	88	19 024 665	185	32	3 273 753	283	25 482 634	....	4	28 678
1909	96	21 892 462	210	16	1 396 154	268	24 645 398	5600	4	24 548
1910	106	23 204 480	229	25	2 508 343	251	21 243 637	....	8	268 741
1911	137	29 310 173	303	24	2 321 016	219	16 839 883	....	7	287 585
1912	165	37 958 050	381	4	400 970	210	17 707 993	5744	1	29 682
1913	185	46 194 737	467	13	1 173 528	168	13 014 153	5372	5	132 298
1914	191	47 485 729	540	6	478 041	139	11 233 532	5244	1	106 858
1915	173	47 239 554	602	7	320 062	92	7 947 497	4265	6	502 645
1916	176	53 140 005	648	7	675 235	98	8 123 624	4213	3	343 272
1917	200	67 196 768	744	5	321 628	113	9 422 285	4913	6	471 373
1918	240	77 662 619	960	1	98 209	129	10 545 400	5065	0	......
1919	259	66 686 930	1114	3	143 118	111	6 921 673	5370	0	......
1920	276	66 441 191	1228	2	80 202	95	5 888 217	4974	0	......
1921	280	71 329 567	1424	1	38 481	108	6 971 034	5348	0	......

*Haulage by gasoline locomotives included as follows: 1907, 2–400 643 tons; 1908, 1–245 513 tons; 1909, 2–81 670 tons; 1910, 3–85 892 tons; 1911, 3–185 836 tons; 1912, 13–1 857 415 tons; 1913, 24–3 580 539 tons; 1914, 28–4 279 106 tons; 1921, 18–942 776 tons.

inclusive indicate a gradual reversal in prominence held by animal and locomotive haulage. (Table 1.) In 1899, 87.1 per cent of the tonnage in Illinois coal mines was handled by animal haulage. Locomotives hauled 2.5 per cent, ropes 7.9 per cent and tramming 2.5 per cent, but in 1921 it appears that both ropes and tramming were practically obsolete and that 91.2 per cent of the coal was moved by locomotives, and only 8.8 per cent by animals.

In the early '90's, several attempts were made to use electric locomotives, some of them meeting with considerable success; but 1899 was the first year in which an appreciable amount of coal was hauled by electric locomotives. Statistics for the number of electric locomotives in use prior to 1907 are not available, separate from the statistics for gasoline and other types.

Pertinent data on mine haulage were collected, in 1914, by the Illinois Coal Mining Investigation and published in Bulletin 13. Twenty-four typical mines that used mule haulage had average conditions as follows: daily coal production, 597 tons; weight of empty car, 1239 pounds; weight of coal per car, 2627 pounds. Similarly in 65 typical mines having mechanical haulage, the average statistics were: daily production, 1667 tons; weight of empty car, 1753 pounds; weight of coal per car, 4450 pounds. There were five mines using the rack-rail type of locomotive and seven using gasoline locomotives. Rope haulage was used in but six mines. All other mines were using trolley locomotives.

Table 2 gives a classification of the three chief systems of underground haulage in use throughout the state in the year 1921. Rope

TABLE 2
LOCOMOTIVE AND MULE HAULAGE IN 1921

System	Mines		Production		Ave. Tons Per Mine
	No.	Per Cent	Tons	Per Cent	
Mules only	109	33.2	9 976 493	12.9	91 527.5
Locomotives only	31	9.4	13 731 010	17.9	442 935.8
Locomotives for main haulage, mules and locomotives for gathering	189	57.4	53 598 971	69.3	283 592.4
Totals	329	100.0	77 306 474	100.0	234 974.1

haulage is not included because its use is very limited and the Coal Reports do not now segregate it. For the mines covered, this table shows how the haulage systems are related to production.

Statistics for the year 1921 covering 324 producing mines in 38 counties of Illinois show that electric haulage was used exclusively in but 31 mines or 9.6 per cent; mules performed all the haulage in 108 mines or exactly one-third; in the remaining 185 mines haulage was "mixed," that is, by both locomotives and mules.

III. The Shaft Bottom

8. *General Importance.*—The term "shaft bottom" applies to the portion of the mine that is contiguous to the bottom of the main hoisting shaft. It includes the terminal tracks for storing the loaded cars while waiting to be hoisted, the storage tracks for empty cars while waiting to be taken back to the working faces, and the necessary motor and supply rooms, foreman's office, pump rooms, run-arounds, shops and waiting rooms.

When it is considered that the shaft location may affect the haulage grades for the entire mine throughout the life of the mine, the importance of preliminary drilling to determine the contour of the coal bed is obvious, in order that the shaft bottom may be located as nearly as possible at the lowest point in the mine and the loaded trips hauled down-grade as much as possible. A shaft bottom on the loaded-car side should be either approximately level or at a grade of 1 to 1.5 per cent toward the shaft. The grades on the empty side of the shaft vary with the method of handling the empty cars.

An adequate shaft pillar should be provided about the shaft bottom to protect the shaft and the surface equipment from subsidence. In too many cases, however, where the original plans called for adequate shaft pillars, rooms have been started in the pillar in order to get coal quickly. In many cases it has proved very poor economy to mine out the coal too close to the shaft, for it should be remembered that this coal is not lost but merely deferred in its extraction to the time when the mine will be abandoned. Typical shaft bottom arrangements are shown in Figs. 12 to 18, inclusive.

The shaft bottom is the heart of the underground workings and is the busiest place in the mine. Here the loaded cars must be promptly hoisted or dumped and the empties returned to the working face to avoid blocking the traffic. In some mines from 1200 to 1500 cars are handled on the shaft bottom daily during an eight-hour shift, or an average of two to three per minute. The efficient operation of the whole mine, therefore, depends not only on shaft-bottom arrangement and mechanical equipment, but also on a proper balancing of the haulage from the various divisions of the mine to the shaft bottom which is the main terminal.

The first extensive use of self-dumping cages was in Illinois. At present they represent the prevailing method of hoisting coal, except in the longwall field. At a number of the older and smaller mines and very generally in the longwall field the platform cage is still used, the car being run off the cage at the surface to be dumped. In a few cases, two cars are placed on the cage platform for hoisting, either tandem or side by side. The speed of hoisting at the larger mines gives two to four hoists per minute. Mine cars vary in capacity from two to four tons each.

The chief items to be considered in the shaft-bottom layout are:

Arrangement of tracks to permit the locomotive to land a loaded trip and to obtain an empty trip without delay, so as to prevent interference of one locomotive with another.

Storage space for loads and empties.

Shaft-bottom grades.

System of handling loads and empties, including caging, if the cars are to be hoisted.

Arrangements for safely receiving the men who have been lowered; also adequate waiting room for men who have gathered on the shaft bottom previous to being hoisted to the surface.

Suitable arrangements for handling equipment and supplies, such as timber, oil, waste rock, sump coal, and broken cars.

Conveniently located mine manager's office, locomotive barns, repair and supply shops, pump-rooms and mule stables.

The act of haulage is really completed when the car is placed on the cage ready to be hoisted, but often haulage and hoisting data are not kept separately. Only data upon hoisting, ventilation, and such collateral topics as have an effect upon haulage performance are considered in this discussion.

9. *Delivering Cars to Shaft Bottom.*—It is important that the main-line locomotives be able to land the loaded trips at the bottom and take up the empty trips for the return with the least possible interruption. The likelihood of interference increases with an increase in the number of locomotives hauling to the shaft bottom. With two locomotives, one coming from each side of the shaft, there should be no interference and no delay, provided there is ample storage for

empty cars. Where two or more locomotives come to the shaft bottom over the same route, interference on the shaft bottom between the incoming and outgoing locomotives is probable unless a definite schedule is maintained and proper provision is made in the shaft-bottom layout. Three different ways of preventing such interference, described later in detail in connection with the several shaft-bottom arrangements herein given, are as follows:

(1) Adequate length of double track in each direction from the shaft on the main haulage road, as described under Mine A, p. 56.

(2) Separate outlets from the shaft-bottom empty-storage track to the several sections of the mine, with grade track crossings eliminated by the use of cross-over bridges, as described under Mine C, p. 58.

(3) A trip despatcher or haulage boss on the shaft bottom who is in touch by telephone with flagmen at the junction points, and thus directs the incoming trips.

10. *Storage Space for Loads and Empties.*—Adequate storage tracks for loaded and empty cars, and a suitable arrangement of such tracks and their approaches should be provided, as these items very largely determine the regularity and continuity of cars supplied to the cager for hoisting. A shortage of railroad cars on the surface or an accident in the shaft may cause delay in hoisting; therefore, the shaft bottom should provide adequate storage and flexibility in handling cars and incoming trips.

Data in Table 3 show variations in storage capacity at a number of mines studied, and Figs. 12 to 18 show a number of different arrangements of storage tracks. In Table 3, "Storage capacity loads" means the number of cars that can be stored on the track from the shaft to a point where the incoming locomotive ordinarily is cut off from the loaded trip; and "Storage capacity empties" means the number of cars that can be stored on the empty-car track without interfering with the caging operations or with the passage of the incoming locomotive. Any extension of storage space that interferes with regular operations should not be included as regular storage capacity.

Although the storage capacity on the shaft bottom is figured for a certain number of cars, the varying sizes of trips and times of

TABLE 3

SHAFT BOTTOM DATA, INCLUDING LABOR COSTS

Costs Figured for Daily Averages, Regular Working Force

Mine	A	B	C	D	E	F	G	H	I	J	Ave.
Ave. Daily Tonnage	4500	5200	4500	5000	3800	3600	2600	3400	4000	3200	3980
Ave. No. Hoists, Hour	140	155	110	180	200	105	112	130	167	134	143.3
Total No. Cars Hoisted	1125	1245	860	1440	1600	800	800	1050	1330	1070	1114
Total No. Cars in Use	490	625	510	640	580	450	545	485	600	500	542.5
Ave. Wt. Coal per Car	4	4.3	5.25	3.5	2.3	4.5	3.3	3.25	3.0	3.0	3.64
Storage Capac. Loads	100	100	100	60	50	60	92	100	50	120	83.2
Storage Capac. Empties	160	52	160	60	50	60	72	100	50	90	85.4
Method of Handling Cars:											
Loads	Aux. loco.	Grav.	Grav.	Grav.	Grav.	Aux. loco.	Grav.	Grav.	Grav.	Grav.	
Caging	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	
Empties	Aux. loco.	Grav.	Grav.	Car lift	Car lift	Aux. loco.	Grav.	Grav.	Grav.	Grav.	
Employees:											
Cagers	1	4	1	3	3	1	2	1	1	1	1.8
Spraggers and Blockers	3	6	2	2	3	3	3	2	3	4	3.1
Couplers	2	2	1	2	2	2	1	2	1	1	1.6
Car Distributors and Switchers	1	1	1	1	3	1	1	1	1	1	1.2
Total No. Employees	7	13	5	8	11	7	7	6	6	7	7.7
Total Daily Wages	51.00	95.25	36.50	58.75	82.50	51.00	51.25	43.75	43.75	51.00	56.28
Shaft Bottom Labor Cost in Cents per ton	1.13	1.83	0.81	1.18	2.17	1.42	1.97	1.29	1.09	1.59	1.42

NOTE: General items, as Oiling, Cleaning, Sump, etc., are not charged to costs.

arrival often prevent the rated capacity from being available. The location of the connections between the main bottom tracks and the run-around tracks, often called "the motor runs," and the points where the locomotives are cut loose from the trip determine the storage capacity of the shaft bottom to a great extent. For example, this cut-off point may be so located that when one locomotive follows another into the bottom on the same side, the second locomotive will be delayed until the last loaded car of the first trip has passed the entrance to the motor run, and the first locomotive will be delayed until the second loaded trip has cleared the junction point between the loaded and empty tracks on the main entry, unless there is a double track on the main haulage road.

11. *Handling Cars on Shaft Bottom.*—There are three distinct operations in connection with the handling of cars on the shaft bottom:

(1) Delivering loaded cars to the cager after the main-haulage locomotive has been cut off.

(2) Caging.

(3) Taking empty cars from the cage to the empty storage track.

Delivery of Cars to Cager

There are three methods by which the loaded cars after being cut off from the locomotive may be delivered to the cage; first, by pushing and spragging, second, by car haul, and third by a small locomotive running on a center track.

(a) When the control of the mine car after the locomotive has been cut off is left entirely to the spragger, the grade toward the shaft is usually about 1.5 to 2 per cent from the locomotive cut-off point to a point about two car lengths from the cage, and from this point on to the shaft the grade is increased to about 3 per cent so that the loaded car may have sufficient impetus to bump the empty car off the cage. Too steep a grade on the shaft bottom is dangerous for the spraggers and switch-throwers.

If there is a slight up-grade on the approach to the shaft bottom so that the locomotive must continue pulling until a cut-off switch is reached, such a switch should be automatically thrown by the locomotive. If the speed at which the trip is cut off is excessive there is danger of the cars getting beyond control. If the same employees always handle the loaded trips, they become skilled in their work and can accurately judge the distance the cars will run and the number of sprags necessary, so that very few run-away trips occur although this method of handling cars is extensively used. Handling by gravity and spragging is a continuation of the method employed when the cars were much smaller than those commonly used now. The present tendency is to install heavier equipment both in mine cars and in locomotives so that the problem of controlling the cars by hand under such conditions is much more difficult than formerly.

Several types of sprags are shown in Fig. 5. The ordinary double-cone spoke sprag *a* is thrust between the spokes of the moving wheels, thus causing the wheels to slide on the rail; the block sprag *b* may be placed on the rail in front of the wheel, or it may have a flat face cut out to fit the flange of the wheel *c, d,* and be placed in front of the wheel. The block form gives much greater surface of contact than the cone type and one block is as effective as several cone sprags. On account of the smaller number of block sprags required, there is also a saving in time in the application of sprags.

(b) A car haul consists of an endless chain to which are attached at regular intervals "catches" that engage the axles of the cars and push the latter forward toward the cage. A similar device may be used for moving the empty cars on the opposite side of the cage.

(c) By means of a relatively small locomotive running on a third or center track (Fig. 6), and provided with an arm that can be moved in and out transversely on either side of the locomotive, cars on either track are pushed forward toward the cage. The advantages of this system are that at all times the cars are under control, and they may be moved in either direction as desired, the safety on the bottom being thus increased. A car-haul can control the movement of cars for the length of its construction only—perhaps 75 feet—whereas an auxiliary locomotive will regulate the travel of the loads or the empties for the entire length of the bottom with the exception of about 50 feet on either side of the shaft. Another fact in favor of the auxiliary locomotive is that it proves useful in replacing derailed cars anywhere on the shaft bottom.

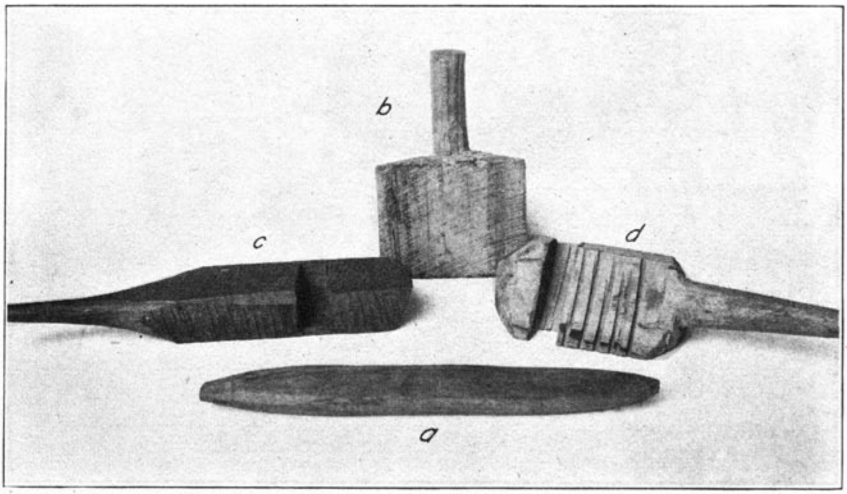

Fig. 5. Types of Sprags

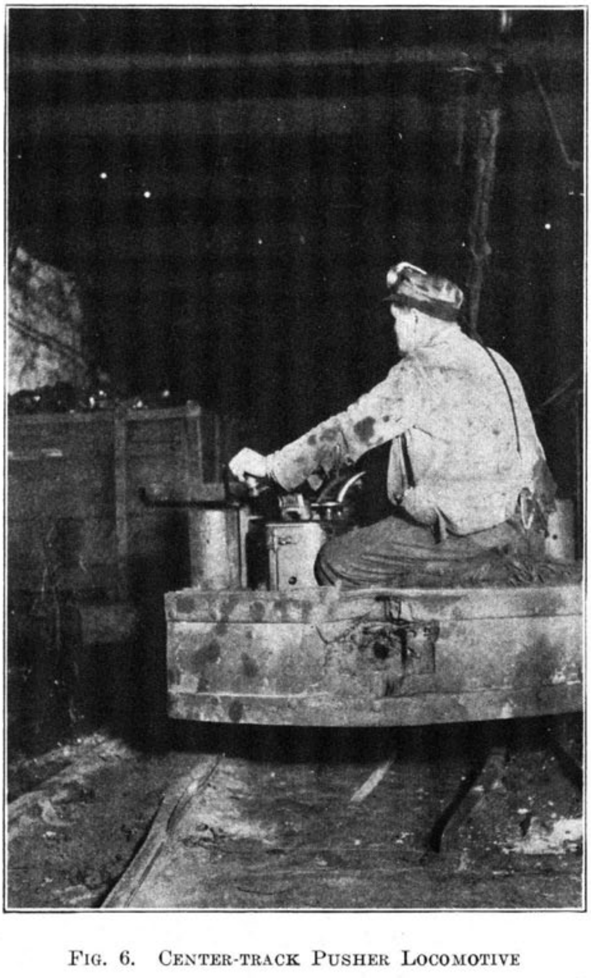

Fig. 6. Center-track Pusher Locomotive

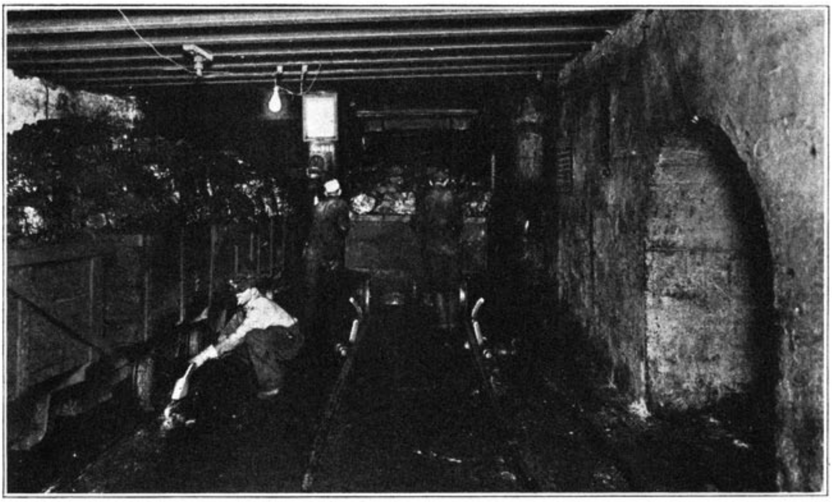

FIG. 7. AUTOMATIC CAGING DEVICE AND USE OF SPRAG

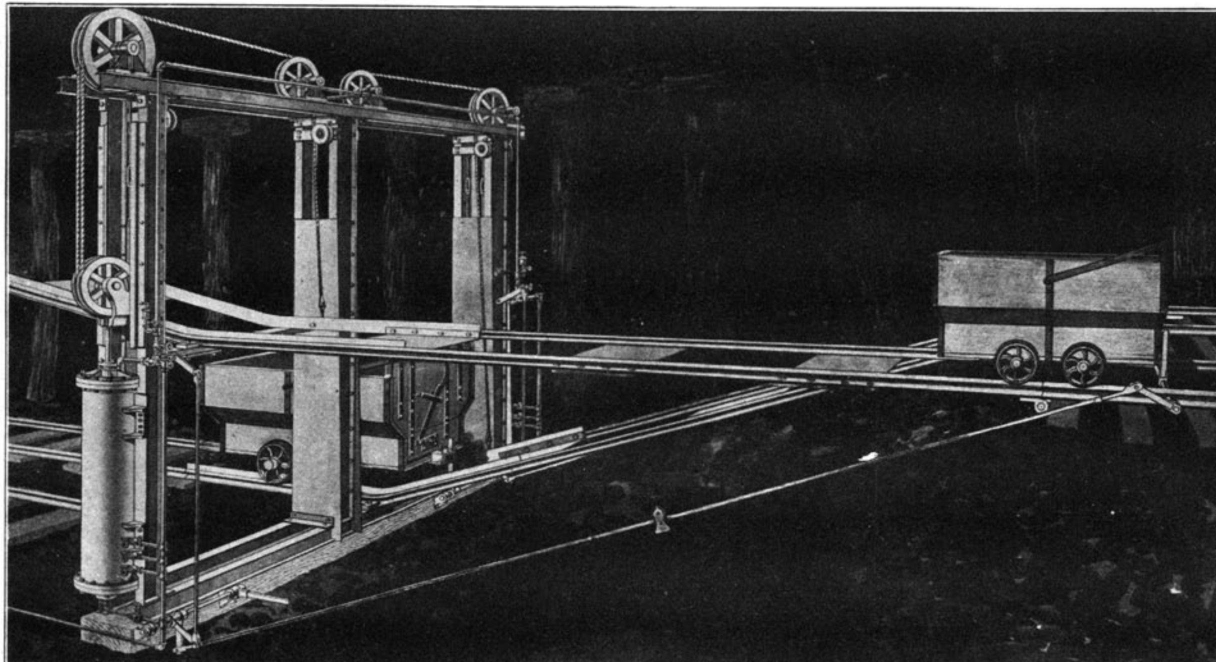

FIG. 8. CAR LIFT

Caging

Cars are caged by hand or by an automatic caging device, the loaded car bumping the empty car off the cage. Fig. 7 shows an automatic caging device used at most of the newer mines. A pair of dogs nearest the shaft is opened automatically when the cage strikes the bottom, thus permitting the loaded car to be pushed upon the cage. At the same time a second pair of dogs, farthest away from the shaft, is thrown across the track and stops the incoming car. As the cage rises off the bottom, the dogs that were across the track open and the other pair fall back over the track, thus permitting the loaded car to be pushed forward ready to be put on the cage when it next descends. In some instances, caging is carried on so rapidly and with such precision that the signal to hoist is given before the car has come to rest on the cage.

Removal of Empty Cars

Owing to unfavorable natural conditions it is often necessary to do considerable grading in order that an empty car may run by gravity from the cage to the empty-storage track. An arrangement often used when the cars are caged from one side only is to have the track leading from the cage terminate in a "kick-back" which gives the empty cars sufficient impetus to cause them to run by gravity to the empty-storage tracks, where they are formed into trips. By means of a mechanical car lift (Fig. 8) the empty car may be raised 8 to 12 feet and thus, in running down a grade, be given an impetus that will cause it to run by gravity directly to the empty-storage tracks; or from the car lift it may go first to a "kick-back" and thence to the storage track.

A three-track arrangement with an auxiliary locomotive operating on the center track, similar to that described as being used on the loaded side of the shaft, has many advantages for handling heavy equipment and gives a very flexible method of operation. A greater length of shaft bottom on the empty side is necessary for this arrangement but it provides increased storage space for empty cars and also a convenient way for shifting broken cars.

12. *Handling Men on Shaft Bottom.*—The shaft-bottom arrangements for handling men depend upon whether the hoisting shaft for coal is used also for hoisting men, or whether an auxiliary shaft is

used for men and materials. According to the present agreement in Illinois between the mine operators and the United Mine Workers of America, the men are hauled to and from the shaft bottom and inside partings of the mine. Consequently, greater numbers of men may be expected to congregate at one time on the bottom than was the case when the men walked to and from their work. This condition should be taken into account in the arrangement of the shaft bottom.

When the men are hoisted at the main hoisting shaft it is common practice to run a man cage about nine o'clock in the morning, one or more during the noon hour, and one during the afternoon when the shot firers enter the mine. These are in addition to the cages at the regular morning and afternoon lowering and hoisting times. The activity on the shaft bottom during the working hours makes traveling dangerous, and in a number of mines special traveling ways are provided to the waiting rooms required by the Illinois Mine Law so that men are kept away from moving cars.

The approach to the hoisting shaft and to the escape-way at the air shaft should be carefully chosen and easy of access. The waiting rooms are usually so located that, in passing to the cage, the men pass the "checking" room and turn in the checks given them on entrance in the morning. At one mine a waiting room has been made by placing flooring about seven feet above the main tracks and providing seats in the room thus made. Such an arrangement is possible of course only when there is unusual headroom on the bottom. Such gathering places for men offer an opportunity for the display of safety signs and pictures. Indeed, moving pictures relating to safety might also be shown while the men are waiting to be hoisted, though no instance of this being done is on record.

13. *Handling Supplies, Equipment, and Refuse.*—The problem of handling equipment, supplies, broken cars, etc. is most successfully solved where there is a separate man and materials shaft, which is usually the air shaft also. The mines provided with separate hoists at the air shaft have this advantage also that all refuse can be hoisted and taken to the dump pile without either interfering with the hoisting of coal or requiring any changes of chutes in the tipple, as is necessary when the same self-dumping cages are used both for coal and rock.

14. *Handling of Sump Coal.*—The method generally employed for removing the coal that falls into a sump is to have it hand shoveled into a mine car. In addition to the inconvenience of this method there is a certain amount of danger attached to it, due to unintentional lowering of the cage upon the man in the sump or from objects falling down the shaft. One solution of this problem is a track laid into the sump under the cages at right angles to the cage tracks. Two mine cars are run into this sump, one under each cage. When they become full of coal they are withdrawn and replaced by empty cars. Such an arrangement is possible only where a crosscut or entry on the cage landing opens at the end of the shaft, and where the conditions are such that suitable grading may be done in order that the cars may be hauled from under the cage.

At the Bunsenville Mine of the U. S. Fuel Company, provision has been made whereby cars may be run under the cage landing and there loaded from a hopper with a drop-bottom attachment. These cars are then pushed to an electrically operated auxiliary hoist and hoisted a distance of 13 feet to the shaft-bottom level.

At some mines a removable box with a drop bottom or side has been placed in the sump and fitted into the guides so that when full of coal it can be attached below the cage and hoisted the height necessary to permit the contents to be discharged through a detachable chute into an empty car on the shaft bottom.

15. *Arrangement of Offices, Stables, Shops, and Supply Rooms.*—At many mines greater attention could advantageously be given to the provision of larger and more adequately equipped mine manager's offices on the shaft bottom, where managers and their assistants may meet for consultation.

Where mules are used they are generally stabled underground near the shaft bottom. The construction of underground stables has been specially provided for in the Illinois mine law, which specifies a separate air split, fire-proof construction throughout, automatic sprinklers, fire-proof doors, covered bins, and covered cars for hay and grain. The worst accident in the history of Illinois mining, the Cherry mine fire, was due to the careless handling of hay. The standard stable of one large company operating in Saline County is shown in Fig. 9. The construction of this stable is fire-proof throughout, consisting of steel roof support, full-height concrete walls and concrete floors, stall partitions, feed boxes, feed bins, and harness rooms. The stable feed bins and harness rooms are fitted with steel doors. Separate hay and grain boxes are provided for each stall, with one water trough for two stalls. An automatic sprinkler system is installed directly over the feed boxes. The stall partitions are built of concrete 42 inches high, topped with a wire screen 24 inches high. Hooks are provided at each stall for holding the harness when not in use. A track in the center of the stable is used for handling supplies and loading out manure. Additional space is provided for washing the mules. Drainage is provided by a tile conduit extending under the full length of the stable. Every Saturday the stable is thoroughly washed out with a hose and thus maintained in a sanitary condition.

The central point for storing locomotives over night or during idle periods should be readily accessible from the different sections of the mine. The locomotives are left standing along the main tracks with the trolley poles down, if no barns are provided for their storage. Where storage-battery locomotives are used, provision is made for charging stations and these are usually installed in a special locomotive barn.

In connection with locomotive haulage, it is becoming more and more common to provide on the shaft bottom a fairly complete repair shop in which there are often one or more motor pits. Moreover, time might be saved where gathering locomotives are used, by establishing at central points in the inner workings auxiliary repair shops fitted with motor pits for minor repairs. This has been done at one mine in Saline county in connection with an underground sub-station. For line repairs and bonding of the rails and also for certain minor repairs to locomotives, a specially-equipped portable repair car may be maintained.

Usually broken cars are hoisted and taken off at the ground landing to be repaired in the repair shop on the surface; but at a few mines provision has been made for making small repairs to mine cars underground, particularly to the running gears, couplings, drawbars, etc. A repair room for this purpose is sometimes located near to and connected with the empty-storage track.

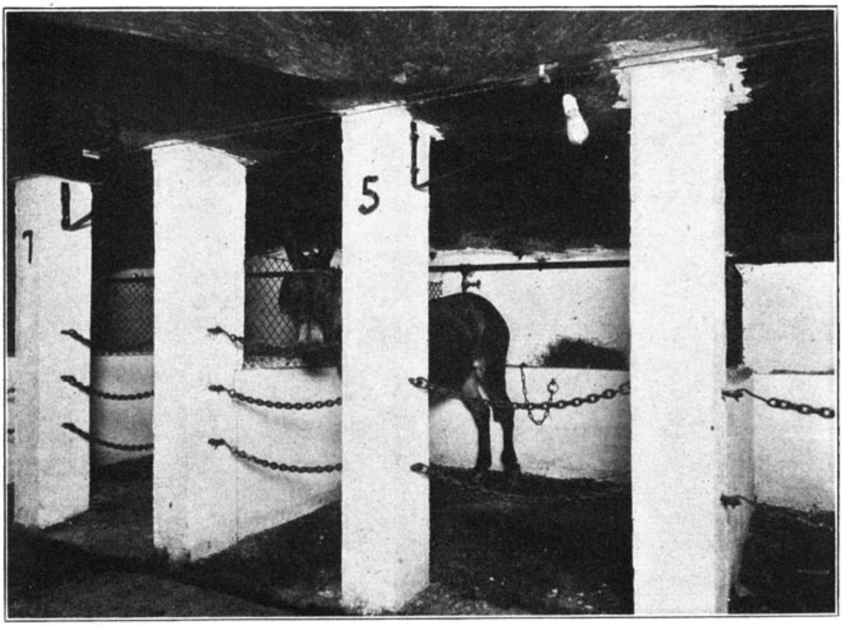

FIG. 9. UNDERGROUND STABLE

FIG. 10. UNDERGROUND SUPPLY ROOM

The following is a report of locomotive repair items for one day at one of the larger mines in Illinois where 7 main-line and 19 gathering locomotives are used.

Main-Line Locomotives	Nature of Repairs	Time Spent in Repair Shop	
No. 21	Arc lights	0 Hr.	15 Min.
21	Suspension bar down	0	55
		—	—
		1	10
Gathering Locomotives			
No. 26	Reel ball race	2	30
9	Reel circuit ground	0	15
8	New trolley pole	0	10
16	Reel stud broken	0	30
23	Reel resistance	0	52
26	Short circuit	0	21
24	Lead off resistance	0	12
7	Sand-rod broken	0	8
22	New reel armature	0	20
4	New reel armature	3	0
5	Lead blown off reel motor	0	32
12	New trolley pole	0	15
5	Resistance blown up	1	0
		—	—
		9 Hr.	47 Min.

Some companies maintain near the shaft a room well equipped with supplies needed in connection with the operation and repair of mining machines and locomotives. (Fig. 10.) Such a supply room, usually in charge of a storekeeper who checks out materials by a system similar to that generally used on the surface, aids materially in keeping account of the repairs upon each mining machine or locomotive. Oil and grease are sent underground in barrels and are usually stored in an offset to the empty run-around near the oiling station. On account of the fire risk special precautions should be taken when handling and storing this material. Considerable sand is used daily in some of the mines, at one mine eight tons per day being used for sanding the rails. The usual method of handling the sand is to dry it on the surface and then send it below in mine cars for distribution to central points. Sometimes a pipe through a bore-hole from the surface carries the sand to a central distribution point near the shaft bottom.

16. *Shaft-Bottom Support.*—In some mines where there are favorable natural roof conditions and an ample height of coal, very

little support to the top and sides is necessary; but in most mines a large amount of roof and side support must be used. Much greater permanency now marks shaft-bottom construction than formerly and in many of the more recent shaft bottoms concrete arches or steel I-beams, with wood lagging or concrete roofing between the beams, have been installed on the shaft bottom as part of the initial development. Concrete sides serve the double purpose of sustaining the roof supports and the coal ribs.

Three types of permanent construction are shown in Fig. 11. In the first type (*a* and *b*) structural steel is used for the posts and the caps, with plank lagging on walls and roof. In the second type (*c* and *d*) concrete is used for the walls, structural steel for the caps, and the lagging is either plank or corrugated or sheet iron. In the third type (*e*) concrete is used exclusively for the walls and the roof, the roof being an arch.

Cost figures for these three general types of support have been furnished by Allen & Garcia, Chicago, Illinois, the estimates being based upon the average cost of the various materials in place as of August 1, 1921, and upon sets being placed at 4-feet centers. The constructions illustrated are calculated to withstand top pressures of 750 pounds per square foot and side pressures of 500 pounds per square foot. Concrete is estimated as costing $30 per cubic yard; structural steel, 8 cents per pound; iron, 10 cents per square foot; and lumber, $65 per thousand board feet.

For a shaft bottom or double-track entry, Fig. 11*a*, using 6-inch H-beams for posts and 12-inch I-beams for caps, the cost was approximately $24 per lineal foot.

For a single-track entry, supported exclusively by structural steel, Fig. 11*b*, 6-inch H-beams are used for both posts and caps. The estimated cost per lineal foot was approximately $18.

In the second general type of construction, for both single-track, Fig. 11*c*, and double-track, Fig. 11*d*, with walls 18 inches thick at the bottom and 12 inches thick at the top, and using for the narrow entry 6-inch I-beams for caps, and for the double-track entry 12-inch I-beams, the cost per lineal foot in the two widths of entry was respectively $25 and $30.

For the third type, Fig. 11*e*, in which concrete is used exclusively with walls of the same thickness as in the preceding type and the

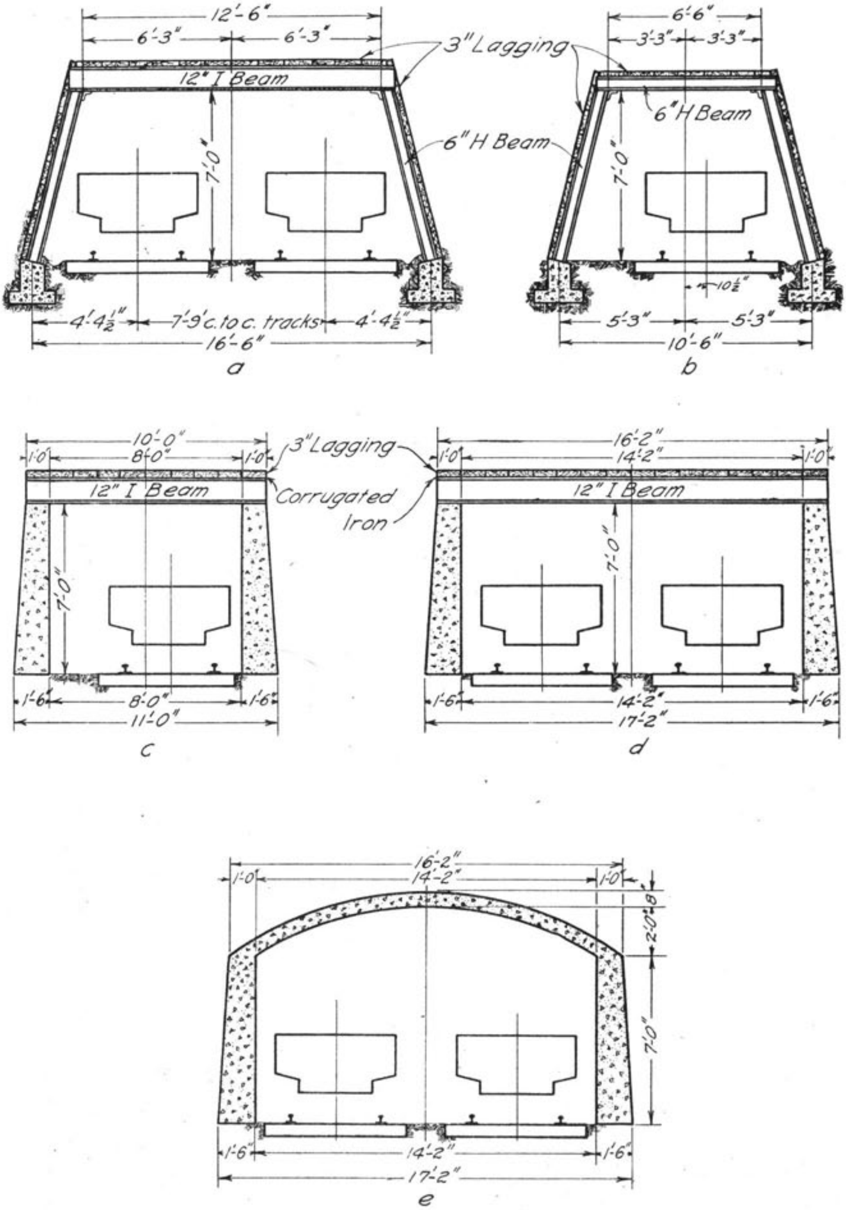

FIG. 11. TYPES OF PERMANENT SHAFT-BOTTOM SUPPORTS

arch uniformly 8 inches thick, the cost per lineal foot was approximately \$31 for the dimensions given.

A coating of cement put on roof and ribs with a cement gun is being extensively experimented with in an effort to prevent spalling off of the coal. This cement coating should not be applied until the roof and ribs have been thoroughly brushed or cleaned to remove all dust and loose fragments of coal, thus ensuring a solid foundation for the cement, which would otherwise spall.

17. *Typical Shaft-Bottom Plans.*—Typical shaft-bottom plans for several Illinois mines are shown in Figs. 12 to 18, inclusive. A characteristic feature of the bottoms in most of the newer mines in Illinois is that the shafts are in the shaft pillars off from the lines of main haulage and the tracks leading to and from the shafts are approximately at a right angle to the main haulageways. This is illustrated in Fig. 13 and is commonly known as the "A" type of shaft bottom. If the empty tracks leading from the back of a shaft to the main haulageway are not parallel to the incoming loaded tracks, but at an angle of 30 deg. to 45 deg., as shown in Fig. 15, the bottom is said to be of the "V" or triangular type.

Data on the general layout, operation and cost of operation for ten mines are given in Table 3. A detailed description of the particular features of the plans and the methods of operation follows. The term "bottom men" as used in this bulletin includes the men engaged in handling the loaded cars, i.e., cagers, spraggers, switchers, and couplers but not the oilers and sump men who work on the bottom, but do not handle the cars. The costs are based on the 1920 wage scale as follows: motormen, \$7.50 per day with an additional allowance for hauling men to and from the partings, making the wage about \$8.03 per day; trip riders and cagers, \$7.50; couplers, switchers, spraggers, \$7.25.

Mine A

This shaft bottom (Fig. 12) has a three-track arrangement on each side of the shaft. The main-line locomotive, upon reaching the shaft bottom with a trip of loaded cars, is stopped at the point *a* and the locomotive cut off. A ground switch is thrown by the trip rider who then gets back upon the locomotive, which proceeds to the empty storage track. A six-ton auxiliary locomotive (Fig. 6), which is on

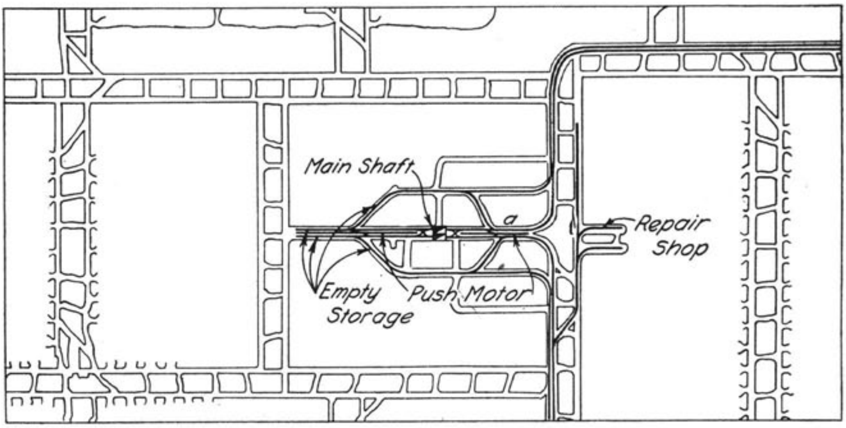

FIG. 12. MAP OF SHAFT BOTTOM—MINE A

the middle track and is provided with an extension arm, then moves the trip under complete control to the shaft where it is caged by an automatic cager.

On the empty-car side of the shaft another six-ton locomotive with a movable arm collects the empty cars as they come from the cage and places them on the empty-storage tracks. In this mine, 14 locomotives haul directly from the working face to the shaft bottom, seven coming from the north and seven from the south side of the mine. At the same mine, the double track extends for 2500 feet on the main haulage entry in each direction from the shaft bottom. This permits the locomotives to proceed on their return empty trip without interruption from the incoming loaded trips. This double-track arrangement also permits the entire number of locomotives if necessary to concentrate near the shaft bottom with loaded trips, giving in effect a very large loaded-storage capacity which may include every car in the mine without interfering with the empty return tracks. The empty-car storage shown in Fig. 12 is ample for ordinary operation of the mine and provides for the storage of about 45 cars on each side of the shaft. Delays on the bottom at this mine are small although an average of 1125 cars are hoisted daily, the empty cars weighing 2750 pounds and holding 4 tons of coal. The shaft-bottom force handling cars includes 1 cager, 3 spraggers, 2 couplers and 1 car dis-

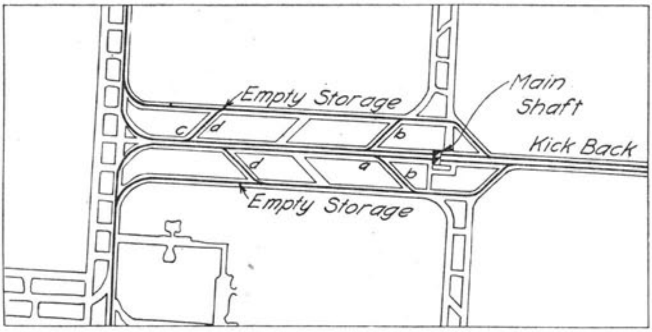

FIG. 13. MAP OF SHAFT BOTTOM—MINE B

tributor, at a total daily wage of $51 according to the 1921 wage scale, or 1.13 cents per ton.

Mine B

On this shaft bottom (Fig. 13) two tracks lead to and from the shaft. The main-line locomotives usually cut off from the trips at a point *a* about 100 feet from the shaft and, after passing through a switch that is automatically thrown, proceed through the motor run cross-cut *b*. From the point *a* to the automatic cagers at the shaft the loaded cars are controlled by spraggers. The empty cars are run by gravity to a kick-back and thence to the empty-car storage track where they are formed into trips ready for the locomotives that come through the motor run *b*. Of the six locomotives that come to the shaft bottom, four are of the 15-ton type and are used for main-line haulage only, while the remaining two, which are of the 8-ton reel-and-trolley type, are used for gathering as well as for main-line haulage.

From 1200 to 1500 cars are caged per day on this bottom. Occasionally there is some congestion when the trips reach the bottom in rapid succession, due to lack of empty-storage space and a single track on the main haulage roads. This congestion could be obviated by double-tracking the main haulage roads for a distance of 200 to 300 feet inbye from said junction with the empty-storage tracks, and by increasing the empty-storage trackage. This could be accomplished by cutting off the locomotive at the point *c* and having it go through the cross-cut *d*, the loaded cars being controlled from *c* to the cager by spraggers.

The average daily tonnage hoisted at this mine is 5200 tons or 1245 cars, each holding 4.3 tons. The average hoists per hour are 155 and the bottom employees are 4 cagers, 6 spraggers and blockers, 2 couplers, and 1 car distributor and switcher. The total daily wage according to the scale prevailing in 1921 was $95.25, giving a shaft-bottom labor cost per ton of 1.83 cents.

Mine C

The bottom arrangement (Fig. 14) provides for a separate haulage way to each of the four sections of the mine 1, 2, 3 and 4. There are two tracks on each side of the shaft, and after the locomotive is cut off at the point *a* the cars are moved to the shaft by spraggers and automatic cagers. The main-line locomotives approach the inbye end of the shaft bottom, *b*, by different routes, but all of them are detached from the loaded trips at the point *a* and pass through the motor runs, *c*, to the empty storage tracks. At two places, *e*, where crossings are necessary, overhead bridges permit the loaded trips

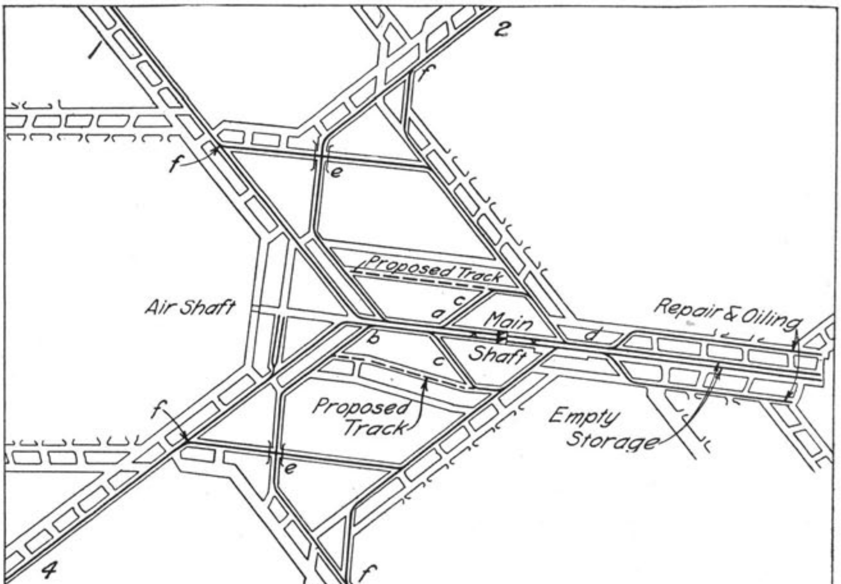

FIG. 14. MAP OF SHAFT BOTTOM—MINE C

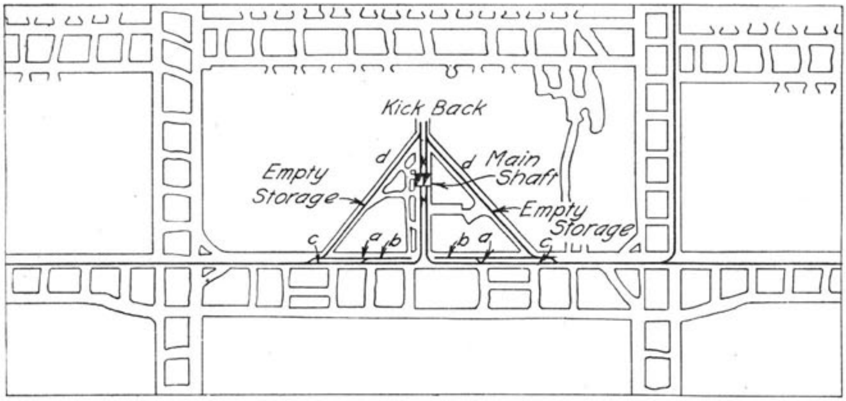

FIG. 15. MAP OF SHAFT BOTTOM—MINE D

to pass over the empty trips. From the junction points, *f,* of the loaded and empty tracks the haulage roads inbye are single track. The two "proposed tracks" parallel to the main bottom were intended as an extra locomotive run-around for sections 2 and 3, but they have not been needed to date.

The empties run by gravity from the cage to the empty storage track, *d,* where they are coupled to the empty trips.

With this arrangement a daily output of 4500 tons or 860 cars, each holding 5.25 tons of coal, is handled with 1 cager, 2 spraggers, 1 coupler, and 1 switcher, at a daily labor cost of $36.50 or 0.81 cents per ton.

Mine D

The roads leading to the shaft bottom (Fig. 15) are single-track and the locomotives are cut off along the main entry at *a* and, by flying a switch, run upon the parallel side track *b*. After the trip has passed the motorman brings the locomotive up behind the trip and pushes it to the automatic cager if this be necessary, or the trip may have sufficient momentum to run to the cager and may have to be controlled by sprags. The locomotive backs to the junction joint in the empty-storage track, *c,* and there picks up the empty trip. A mechanical car-lift and kick-back sends the empties by gravity to the empty-storage track, *d*.

Two locomotives operate in each of the east and west sections of the mine. Movements of trips to and from the shaft bottom are controlled by telephone communication from the several partings to the haulage boss who knows that the road is clear before giving the right-of-way; thus only one locomotive from each section is permitted on the shaft bottom at one time.

Five thousand tons or 1440 cars per day are handled on this bottom by 8 men, 3 cagers, 2 spraggers, 2 couplers, and 1 switcher, at a total labor cost per day of $58.75 or 1.18 cents per ton.

Mine E

This shaft bottom is that shown in Fig. 16. The locomotives are detached from the loaded trips on the main entries, the loaded cars proceeding by gravity to the shaft under control of sprags. Caging is done by hand. The empty cars are elevated by a mechanical car-lift and run by gravity from a kick-back switch to the empty-storage track. The daily output is 1600 cars or a total of 3800 tons. The shaft-bottom force includes 3 cagers, 3 spraggers, 2 couplers, and 3 switchers at a total daily labor cost of $82.50, or 2.17 cents per ton.

Mine F

The shaft-bottom arrangement is similar in general to Mine A, but the loads are pushed by ten-ton locomotives operating on the

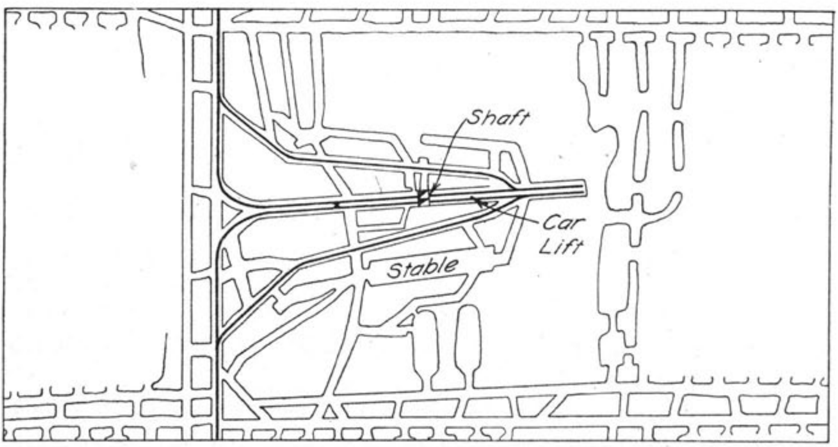

FIG. 16. MAP OF SHAFT BOTTOM—MINE E

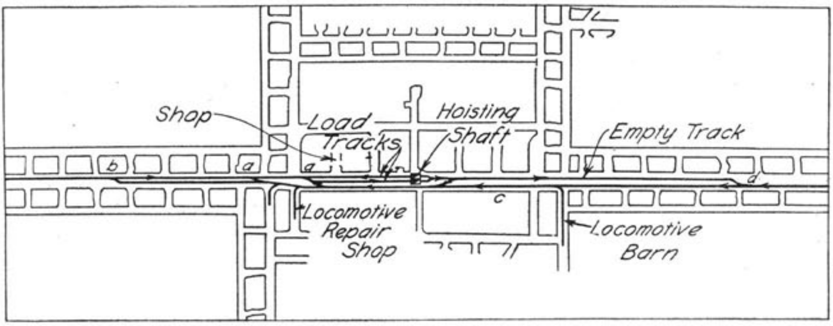

FIG. 17. MAP OF SHAFT BOTTOM—MINE I

middle of three tracks instead of by a six-ton locomotive as in Mine A. Only two locomotives come to the bottom, one from each side of the mine, and a combined main and gathering system is used; whereas in Mine A the locomotive hauls directly from the working face to the bottom, the trains consisting of from 10 to 20 cars. The empty cars are elevated by an electrically operated drag-line and then run by gravity to the empty-storage track.

With the present arrangement, and hoisting per day 800 cars that hold 4.5 tons each, the labor force is 1 cager, 3 spraggers, 2 couplers, and 1 switcher. The total labor cost is $51.00 per day, or 1.42 cents per ton.

Mine G

The shaft bottom is triangular in shape, similar to that shown in Fig. 15. There are two tracks on the shaft bottom and cars are controlled by spraggers after the locomotive is cut off. On the main east approach there is a slight up-grade, and a small electric drag-line is employed to pull the loads a short distance upon the main track. An automatic cager is used and the empty cars run from the cage to the empty-storage track by gravity. The location of the motor run is similar to that in Mine B and the empty-storage tracks extend beyond the shaft, as in Mine C.

For an output of 2600 tons per day, or 800 cars of 3.3 tons capacity, the labor force is 2 cagers, 3 spraggers, 1 coupler, and 1 switcher, at a labor cost of $51.25 per day or 1.97 cents per ton.

Mine H

This shaft bottom is similar to Fig. 13. The daily output of 3400 tons is handled in cars holding 3.25 tons each, by 1 cager, 2 spraggers, 2 couplers and 1 switcher, at a total shaft bottom labor cost of $43.75, or 1.29 cents per ton.

Mine I

This shaft bottom, Fig. 17, differs from the A or V type commonly used in Illinois, as the hoisting shaft is in line with the main entries that extend east and west from it. Coal is hauled to the shaft bottom from both directions, but caging is done from the west side of the shaft only. The locomotives are detached from the loaded trips from the west at one of two points *a* and obtain their empty trips at *b*. The loaded trips from the east are pulled past the shaft on track *c* and backed in on the loaded tracks at *a*. The locomotives that are hauling to the east side go along *c* to the entrance to the empty storage, *d*, to obtain their empty trips.

The repair shops are conveniently located on the west side of

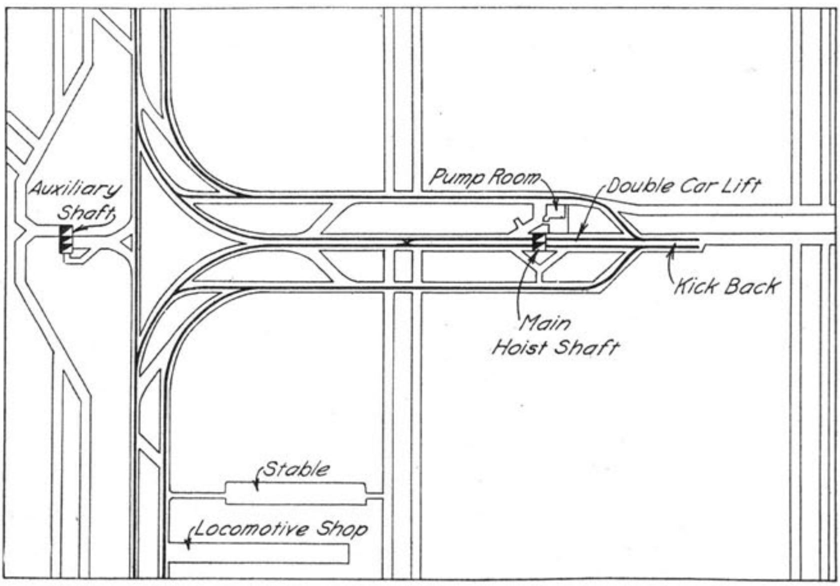

FIG. 18. MAP OF SHAFT BOTTOM—MINE J

the shaft, and the motor barn in which is the charging station for the storage-battery locomotives, on the east side of the shaft. A switch is provided near the shaft for sidetracking cars for oiling.

For an output of 4000 tons per day, or 1330 cars each holding 3 tons, the labor force is 1 cager, 3 spraggers, 1 switcher, and 1 coupler, and the total cost per day $43.75 or 1.09 cents per ton.

Mine J

Fig. 18 is a sketch of a shaft bottom somewhat similar to that in Mine E. Here, however, the entries are parallel. The empty cars can be hauled out along either of the main entries to the north or to the south. The daily production averages 3200 tons and is hoisted at the rate of 134 cars per hour with a shaft-bottom force of 1 cager, 4 spraggers, 1 coupler and 1 switcher, at a daily labor cost of $51.00 or 1.59 cents per ton.

18. *Shaft-Bottom Delays.*—At one mine a detailed study of delays on the bottom was made for one day, and the results are plotted in Fig. 19. Starting at 7:00 A.M., as shown by the diagram, there were 78 loaded cars on the bottom ready to be hoisted. There were also 8 empties. The loads were hoisted by 7:40 but the first trip did not reach the bottom until 7:57, thus causing a delay of 17 minutes. The diagram also shows delays in hoisting extending from 8:20 to 8:30; 8:50 to 9:00; 11:11 to 11:15, due to no cars being received on the bottom. Eight times during the forenoon—at 8:05, 8:09, 8:35, 9:07, 9:15, 9:31, 9:40 and 9:56—the diagram shows that the incoming trips reached the bottom just as the last car was hoisted, thus probably causing a slight slowing up in the hoisting. The number of cars in each trip is shown by vertical components of the graph. For instance, at 7:57 the first trip of 12 cars was landed at the locomotive cut-off point. As shown by the number in the circle, the locomotive was standing still one minute before proceeding through the motor run. Letters N and S indicate the side of the mine from which the trips arrived. Occasionally trips arrived simultaneously from both sides of the mine, as at 11:19 A.M.

On the day when this time study was carried out 61 trips came to the shaft bottom. The 24 trips with a total of 357 cars from the N side were delayed 1 hour 19 minutes, and the 37 trips with 878 cars from the S side were delayed 3 hours 24 minutes; that is, the loco-

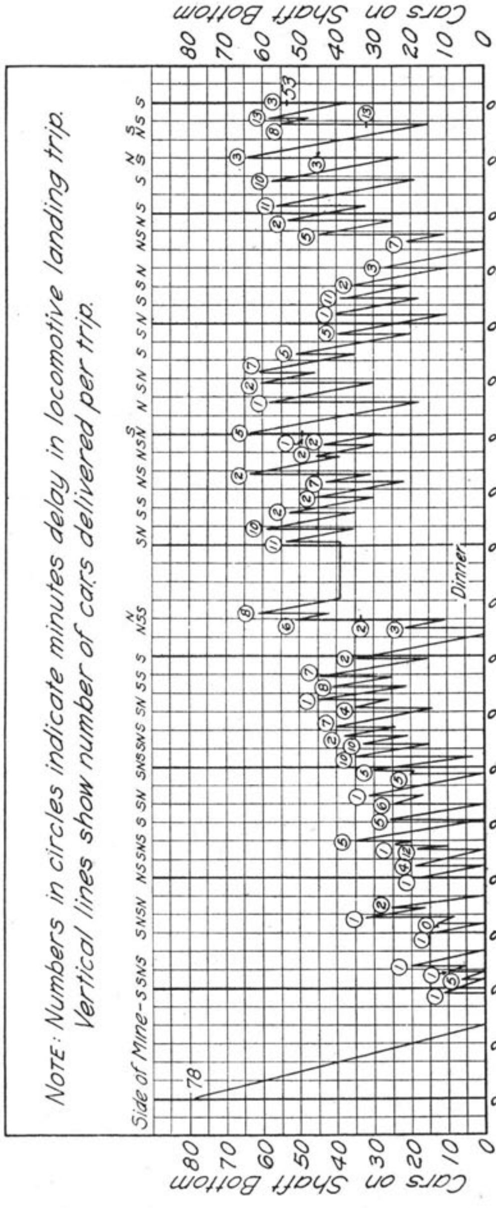

FIG. 19. GRAPH OF SHAFT-BOTTOM OPERATIONS

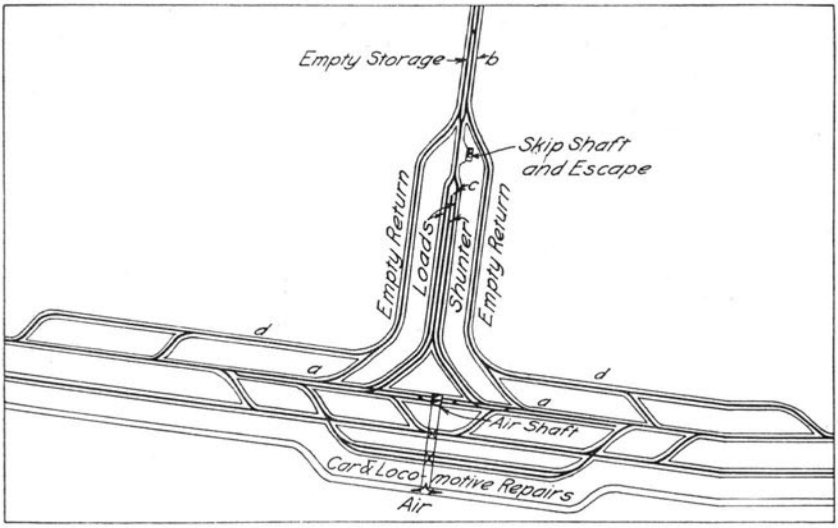

FIG. 20. MAP OF SHAFT BOTTOM FOR SKIP HOISTING

motives waited a total of 4 hours 43 minutes before proceeding from the cut-off point to the empty-storage track.

19. *Shaft Bottoms for Skip Hoisting.*—Prior to 1917 there were in Illinois only three installations at which skip hoists were used. Two of these were at small-capacity mines and the end-gate type of car was used; the third mine had an average daily production of between three and four thousand tons and a bottom-dump car was used.

Since 1918 there have been opened several large shaft mines in which skips, rotary dumps, and solid-end cars are installed. The capacity of these skips is between 10 and 12 tons.* At one of the mines noted, a trial record of 1000 tons in one hour was obtained in 1920. The rotary dump permits the use of the solid-end car, thus giving a more rigid construction, one of the greatest sources of trouble in mine-car construction being the loose end-gate; it also simplifies track layout as the car may be run in either direction. Thus, at one mine the track layout is such that the position of a car on alternate

* A detailed discussion of skip hoisting will be found in an article by Allen and Garcia in the Trans. Am. Inst. Min. & Met. Engr. for 1921, reprinted in "Coal Age," March 17 and 24, 1921.

trips from the shaft bottom to the face is reversed, which could not be the case with the ordinary self-dumping cage layout.

The average shaft bottom arrangements for several mines at which skips are used are shown in Fig. 20. As all these mines are still in the development stage, costs per ton for handling coal on the bottom are not yet available.

The locomotives coming to the shaft bottom are detached from their trips at points *a*, passing thence into the empty-return entries, while the loaded cars move toward the main shaft under control of a pusher locomotive or shunter traveling on the auxiliary track *c*. All loads pass the hoisting shaft over a single track and through a rotary dump. The empties return from *b* through the return entries to be picked up by the locomotives and hauled back to the workings through entries *d*. Double trackage in *b* permits a continuous influx of empty cars without interruptions due to outgoing empty trips. The auxiliary or air shaft is conveniently located on the main haulage entry for cage hoisting when necessary. Fig. 21 shows in vertical cross-section a typical skip-hoisting equipment, including rotary dumps, storage hopper, and automatic measuring hopper.

The shaft bottom at one skip mine includes a rotary car-dumper and skip hoist for a capacity of 7000 to 8000 tons daily. The mine is divided into four sections, northeast, northwest, southeast, and southwest. On the west side of the shaft the locomotives cut off, pass through a run-around, obtain their empty trips in the back entry, and then proceed westward along the back entry to the main west haulage roads. From the east side of the mine the loaded trips are pulled past the shaft along the back entries to the west main shaft approach. The locomotives are detached at the same point as are those from the west, then pass through the run-around to the back entry where they obtain their empty trips and proceed directly to the northeast or southeast portions of the mine. Loaded cars are handled singly by a mechanical car-haul to the weigh scale. A special track is provided for switching broken cars. All material is handled at the auxiliary hoist shaft located to the west of the main shaft. The installation is made complete by a motor-generator room and necessary repair and supply shops near the auxiliary hoist shaft.

At another mine the shaft-bottom arrangement includes a skip hoist for the coal and an auxiliary air-and-materials shaft provided with cages. The main-line haulage locomotives cut off in the main

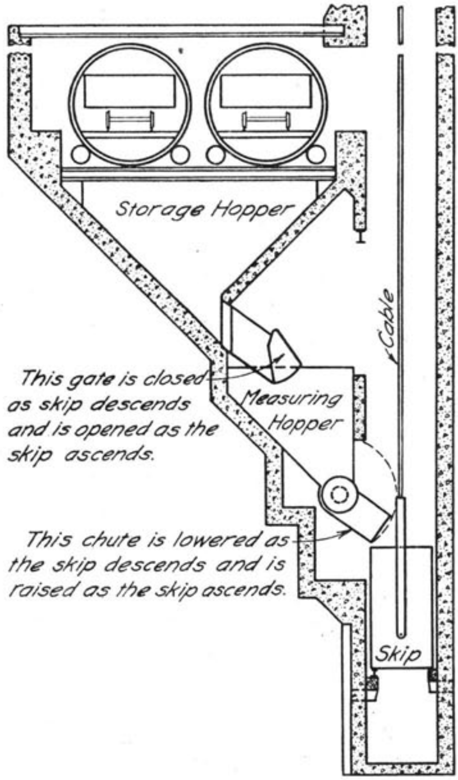

FIG. 21. VERTICAL CROSS SECTION—SKIP-HOISTING SHAFT

entry and go through the empty run-around to the empty-storage track back of the shaft. A pusher locomotive pushes the loaded trip toward the shaft as described in connection with Mine A, page 56.

The empty side of the shaft beyond the skip-pit is provided with two tracks so that the empty cars can continue to pass to the storage tracks, even though the locomotive may be pulling out an empty trip. The auxiliary shaft is so located that cars may be conveniently sent from the main haulage to the cages or returned from the cages to the main haulage.

The arrangement at still another skip mine provides for the loaded cars to be detached along the main haulage road at a point where the locomotive enters the cross-cut leading to the empty run-around, and the loaded trip continues to the dump by gravity, assisted by three car-hauls. These hauls are electrically driven and operated by one dump-man located near the shaft. On the empty-storage side the locomotive is coupled to the end of the trip and, after the cars have passed through the car-dump, pulls it toward a switch, then pushes it through one of the cross-cuts at the right or left to the empty tracks where the main-line locomotives receive their trips. Instead of using car-hauls on the loaded side of the shaft and a locomotive on the empty side, the same arrangement of tracks can be used and the loads carried by gravity to the dump, while the locomotive may pass through the run-around and take the empty trip from the tracks back of the shaft. An arrangement of tracks at the auxiliary shaft is such that the coal may be caged from either side of the shaft and the empty cars returned to the same side from which they were caged.

IV. Main Line and Gathering Haulage

20. *General Considerations.*—Main-line haulage means that portion of the haulage system between the shaft bottom and the gathering partings where the cars are collected from the rooms and made into trips.

The questions to be considered in connection with the main haulage are, therefore, supply of ample power, condition and grade of track, kind and condition of equipment (such as locomotives and cars), speed of travel, suitable and properly-spaced turnouts or pass partings when single track is used, maintenance of a schedule of trips that will cause a minimum of delay at the terminal point and at the pass partings, and prevention of accidents.

The data for the mines studied show that the time spent by the locomotives on the main line is generally less than that consumed in making up trips on the partings, delivering loaded trips on the bottom, and picking up empty trips on the bottom for return to the parting, providing the main-line haulage distance is not more than one mile. The workings from which each locomotive receives the cars should be concentrated so that the locomotive does not have to go to widely separated gathering partings. There should also be an adequate reserve of empty cars on the shaft bottom so that the incoming locomotives are not required to wait for their return trips.

Satisfactory performance on the main haulage is not so much a factor of speed of running as it is of continuous and regular operation. If the haulage system is properly laid out and operated, a high speed of haulage is unnecessary. A slow, uniform speed gives increased safety to employees, both to those engaged in haulage and to others who may be compelled to use the haulage roads. A conservative speed results also in less spillage of coal along the track, less raising of dust, and less cost for repairs to equipment. Usually a maximum speed of six to eight miles per hour can be adopted with increased safety. Only occasionally need the trips be run at higher speeds, as when making up time lost through unusual or irregular causes.

The trolley type of locomotive is generally used for main-line haulage and is fairly well standardized for the conditions that exist in Illinois mines. The locomotives vary from 6 to 20 tons in weight, many of the recent installations being of the 15-ton type. In the larger mines as the length of main-line haul increases the size of the locomotive used for this duty also increases; because generally the greater the capacity per locomotive the smaller number required for a given tonnage, provided the haulage layout is properly designed and there are ample side-tracks. During a shift of eight hours and under suitable operating conditions, a 15-ton locomotive should easily haul on the main line from 1500 to 2000 tons of coal a distance of one mile, but as shown in Table 4 this is being done in very few of the mines studied.

Generally the main-line haulage and gathering are kept separate. At a few mines, however, the locomotives used on the main haulage also gather from the faces and thus run directly from the faces to the shaft bottom with comparatively small trips of cars.

21. *Location of Partings.*—In connection with the gathering of the cars from the rooms, the location of the partings with respect to the room entries materially affects the efficiency of both gathering and main haulage.

It is important that the work of gathering be concentrated so as to reduce the number of partings, the number of cars required, and the distance that either mules or locomotives must travel in unproductive work. The partings should be so advanced that they will always be within a certain standard distance of the working face. This distance varies widely in different mines, but for mule haulage it is generally about 800 to 1200 feet and for locomotives 800 to 2000 feet. In some mines the partings are placed centrally with respect to four panels, the cars being back-hauled from two panels to the parting. The disadvantage of back-hauling from the older panels, in which there may be only a few rooms working, may be more than compensated for by the advantages given to newly developed territory from which the bulk of the hauling is done. Thus each time a parting is moved, whether it be after intervals of two, three or more years, the point should be selected to insure the greatest return for the expense involved; that is, it should be as close as possible to the "center of production" of the tonnage to be produced during a given installation period. Partings are made either by widening a single track entry so that a double track may be installed or by driving an extra passage in

TABLE 4

MAIN LINE HAULAGE IN EIGHT TYPICAL LARGE ILLINOIS COAL MINES

Mine	Ave. Tons Daily	Wt. Car in Tons	Tons Coal per Car	Locomotives			Distances Hauled, Parting to Bottom			Cars per Trip			Cars per Day Parting to Bottom		
				No.	Wt.	Kind	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
B	5200	2.35	4.30	7	15-ton	Trolley	6400	2600	4575	24	7	17	312	70	155
C	4500	2.00	5.00	1 1 1	6-ton 10-ton 15-ton	Tandem Reel and Trolley Reel and Trolley	4660	2710	3670	16	8	13	80	40	70
D	5000	1.20	3.50	1 3	12-ton 15-ton	Trolley	6900	4000	5164	23	10	15	200	40	107
E	3800	1.30	2.30	2 2	10-ton 13-ton	Trolley	8350	4350	6217	27	18	23	380	110	277
F	3600	2.00	4.50	2	15-ton	Trolley	4800	2400	3422	20	10	16	120	40	84
G	2600	1.85	3.30	2	13-ton	Trolley	5200	2000	3867	25	10	18	220	20	137
H	3400	1.60	3.25	1 1	12-ton 13-ton	Trolley	4000	2000	3440	30	20	24	300	80	195
I	4000	1.39	3.00	2 2	12-ton 15-ton	Trolley	8000	4900	6087	26	24	25	235	90	166

TABLE 4 (CONTINUED)

MAIN LINE HAULAGE IN EIGHT TYPICAL LARGE ILLINOIS COAL MINES

Mine	Tons Coal per Day Parting to Bottom			Tons Coal per Day per Locomotive			Ton-Miles Coal per Locomotive			Total Ton-Miles per Locomotive			Loco.-Miles per Day		
	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
B	1350	300	655	1350	300	749	1704	150	788	3386	290	1518	24	9	17.4
C	400	200	350	1925	1105	1502	1121	688	902	2018	1238	1624	35	21	29.0
D	700	140	375	1320	1300	1314	1381	1081	1201	2411	1837	2047	57	38	48.7
E	874	253	637	1127	805	958	1380	920	1162	2950	1960	2479	44	35	40.8
F	560	160	370	1750	1580	1665	1233	912	1073	2330	1724	2028	34	25	29.5
G	735	70	450	1390	1310	1350	1151	620	886	2441	1315	1879	40	18	29.0
H	975	260	634	1805	1365	1585	1151	930	1040	2284	1846	2065	26.5	25	25.5
I	715	270	500	1100	840	1000	1521	890	1146	2931	1715	2209	39	25	30.3

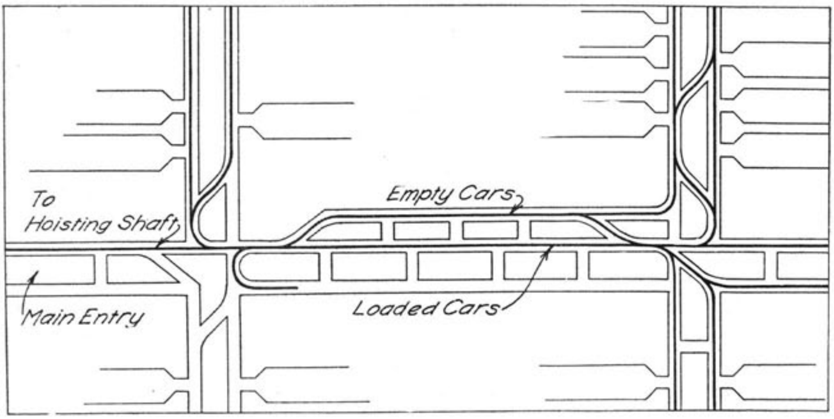

FIG. 22. TYPICAL PLAN OF MINE PARTINGS

the pillar as shown in Fig. 22, which shows also a diagonal arrangement at the entry crossings. Fig. 23 shows the diagonal connection between entries at a prominent mine.

22. *Procedure of Gathering.*—The methods of distributing cars to and gathering them from the rooms vary with the method of working, the agreement between operators and miners, the track arrangement, and the weight of the car. In Illinois, although each miner is assigned a definite room, two men usually load together in one room while an adjoining room is being undercut, so that on any day, even if the entire working force of miners is busy, coal will be loaded in only half the total number of rooms. Unless the car is too heavy or the grade conditions unfavorable, the miners usually push the empty car to the face but the loaded car is always taken from the face by a locomotive or a mule.

Gathering by Locomotive

The procedure in gathering by locomotive usually conforms to one of the three methods, illustrated in Fig. 24 for a panel of 14 rooms on each entry:

1. The empties are left at the room necks but the locomotive goes to the room face for each loaded car. There are two variations of this general method, (a) and (b).

(a) The locomotive pushes the empty trip into a given panel, and distributes the empty cars to and gathers the loaded cars from seven rooms, as numbers 1, 3, 5, 7, 9, 11 and 13, assumed to be working on a given day. Assuming that the miners from rooms 1 and 2 are loading in room 1, an empty car is detached from the inbye end of the trip and delivered into the switch for room 2 which has been or is being cut by the machine men. Proceeding inbye, cars are switched into rooms 4, 6, 8, etc. to room 14. The locomotive takes the loaded car from face of room 13 as far as the switch for room 11, where it is detached from the locomotive. At this time the condition is as shown in Fig. 24*a*. The locomotive next takes the loaded car from room 11. This car is coupled to the car from room 13 and the locomotive proceeds outbye, similarly taking the loaded cars from rooms 9, 7, etc. When the loaded car has been taken from room 1, the trip contains seven cars which are then hauled to the parting. The miners then push the empty cars to the working faces.

(b) The locomotive collects the loaded cars as in (a) and takes the loaded trip to the parting; then, returning with an empty trip, leaves the empty cars in the necks of the rooms that are being worked,

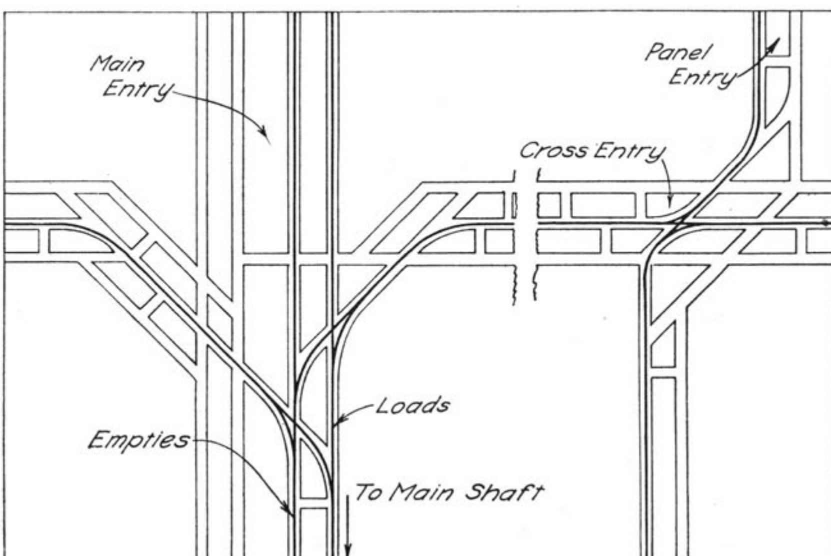

FIG. 23. DIAGONAL CONNECTIONS BETWEEN ENTRIES

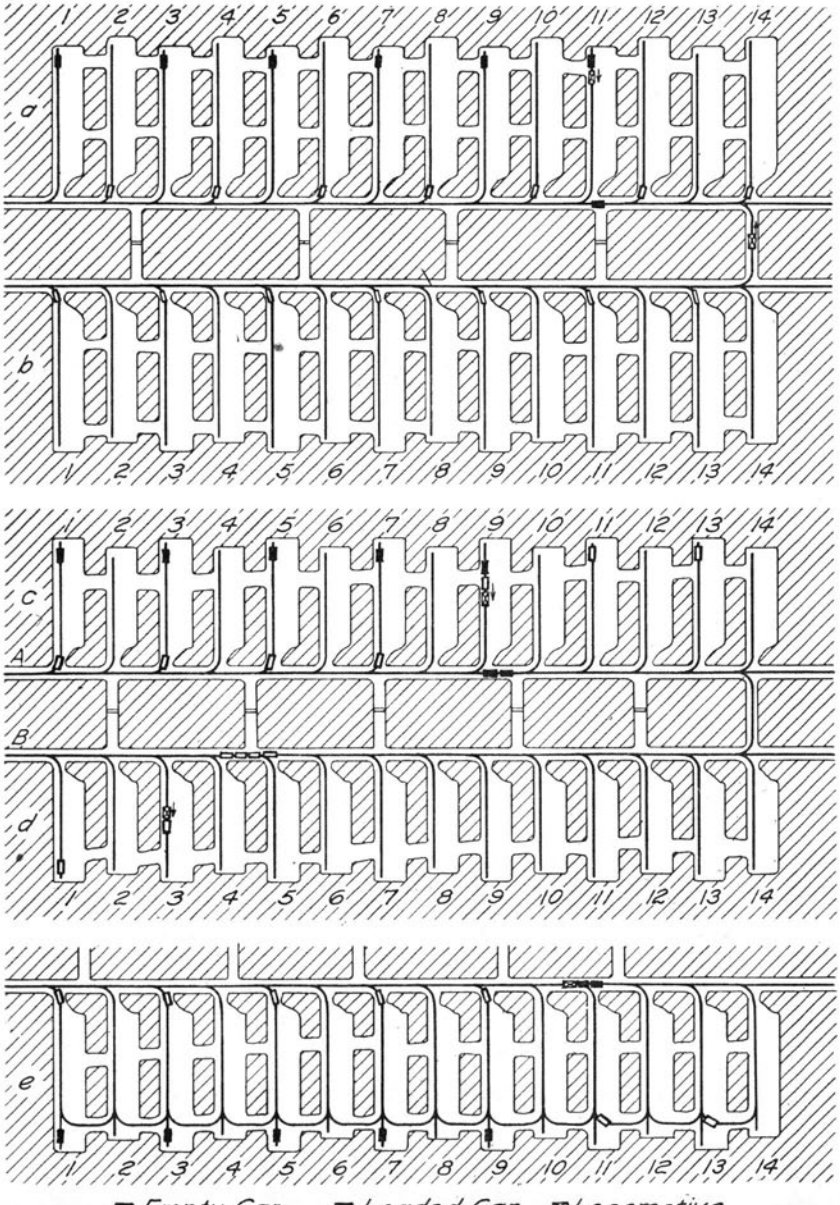

FIG. 24. METHODS OF GATHERING BY LOCOMOTIVES

as rooms 1, 3, 5, etc. After leaving the last empty car in room 13 the locomotive goes through the last open cross-cut to the parallel entry, as shown in Fig. 24*b*, and collects the loaded cars on its way out; or if this is not practicable it proceeds without any cars to another entry to make up a loaded trip.

2. Cars are taken to and from the working face by the locomotive by either of two systems, (c) or (d).

(c) An empty car is cut off at each of the rooms 1, 3, 5, to 13 as the locomotive proceeds along the entry. When the empty trip has thus been distributed and room 13 is reached, the empty car is pushed into the face of room 13 and coupled to the loaded car which is then pulled out and pushed along the entry to a point just inbye of the switch into 13, and there blocked and uncoupled from the empty car. The locomotive then returns into room 13 with the empty car which is pushed to the working face and there left. The locomotive returns to the loaded car at the mouth of room 13 and takes it to the switch just inbye of room 11, where the locomotive is uncoupled. The empty that has been left at the mouth of room 11 is then pushed up to the face and coupled to the loaded car. This procedure is repeated at each of rooms 9, 7, etc. After an empty car has thus been placed at the face of each room the trip of 7 loaded cars is taken to the parting. Fig. 24*c* shows the condition along the entry after the locomotive has gathered two loaded cars from rooms 13 and 11 and is pulling the loaded car out of room 9.

(d) The loaded cars are taken successively from the faces of rooms 13, 11, 9, to 1, and the loaded trip of 7 cars is hauled out to the parting. Returning, the locomotive pushes the empty trip past the switch of room 1, where it is blocked. Then the car next to the locomotive is uncoupled from the empty trip and is pushed by the locomotive to the room face. Similarly, the locomotive pushes an empty up to the face of each of rooms 3, 5, to 13. Fig. 24*d* shows the locomotive pushing an empty car into room 3. The locomotive then proceeds to the parallel entry through a cross-cut at the face; otherwise it backs along the same entry to the main entry and thence to another gathering section. If track is maintained in both of the room entries *A* and *B* it saves time of the locomotive to connect these entries with a track through the last cross-cut. This method requires the loaders to wait while the locomotive goes to the parting with a loaded trip and returns with an empty trip.

3. The empty cars are taken to a room cross-cut switch near the face by a locomotive or mules. In this way the distance that a car is pushed by the miner is decreased. The method is therefore intermediate between methods 1 and 2 in the amount of hand-pushing of the cars, and is particularly applicable also when the cross-cut is worked more as a separate room or place than as an ordinary narrow cross-cut. The empty cars are placed in order just inside the room necks, from room 1 to room 13, as the locomotive proceeds toward the face of the entry. At room 13 an empty is pushed up into the room and placed on the cross-cut switch. The loaded car is then taken from the face to a point on the entry just inbye the switch to room 11. The empty in the neck of room 11 is then pushed to the room cross-cut switch and the loaded car at the face of room 11 is brought to the entry and coupled to the car from room 13, as shown in Fig. 24*e*.

If a room cross-cut is being driven wide so that it is practically a room, and its loaded car is in the cross-cut, the empty will be left just beyond the cross-cut switch along the room track while the locomotive goes into the cross-cut for the loaded car. If the loaded car is at the face of the room the empty is placed on the cross-cut switch and the loaded car then taken from the face of the room.

With this method track need be maintained in one room only, while two or more rooms on each side are served by spur tracks through the last open cross-cuts. In this practice the locomotive enters room 1 with two empty cars which are switched at the face and the loads are then taken out by the locomotive. Extra switchlaying is required each time the room is advanced a cross-cut length, but this outlay is compensated for by the saving of both time and upkeep in room haulage and equipment. Moreover, there is some advantage in a shorter travel of the mining machine in these rooms which, being kept off the entry haulage roads to a greater extent, interferes less with haulage.

Gathering by Mules

For hauling cars in rooms and for short entry hauls mules are effectively used, hence the parting should be kept as close to the working face as practicable. The procedure is very similar to that followed in gathering by locomotives except that smaller trips are necessary. Usually from two to three cars only are hauled to the parting while, at times, on account of adverse grades, a mule can pull only one loaded car. When the driver delivers the empty cars to the room faces he does so on the return trip after the loads have been taken to the parting.

In some mines the loaded cars are taken from the room faces to the entry by mules and there made into trips by the gathering locomotive and taken to the parting. While the locomotive is returning with the empty cars the same driver and mule are employed in gathering a similar trip of cars from the rooms in the adjoining entry. In delivering the empty cars the locomotive pulls the cars into the room entry where the trip rider cuts off one car from the rear of the trip at each working room. If a track has been laid through the last open cross-cut between two panel entries, the locomotive, after delivering all of the empties in one entry, can pass through the cross-cut to the adjoining entry, gather the cars in that entry into a trip, and take them to the parting.

23. *Performance of Main-Line Locomotives.*—In order to secure comparative data in regard to performance at different mines operating under different methods of main-line and gathering haulage, a study was made of the number of cars, the weight of coal, and the distances hauled, both in gathering and on main haulage; thus data were obtained for ton-miles per day per locomotive, which is the measure of performance used for comparing the operation of locomotives on standard surface roads.

Table 4 gives a summary of performance data for main-line locomotives at the mines listed as B to I, inclusively, under the shaft bottom discussion, pages 58 to 63. The mines covered by Table 4 are all large producers and have modern equipment. This table shows a considerable variation in the daily performance at different mines such as the average number of cars hauled per trip, the average number of cars hauled per day, and tonnage or cars per day per parting, but the real basis for comparison is the average ton-miles of coal hauled per locomotive and the average locomotive-miles per day. The detailed study of several of these mines shows a similar variation in the work performed by different locomotives in the same mine, suggesting that at many mines a re-adjustment of locomotive schedule might be made with advantage. With the exception of Mines B and E in each mine of this group the main-line locomotives average over 1000 tons of coal per day delivered to the shaft bottom. At Mine H two locomotives average 1585 tons per day with an average haul of 3440 feet. The total ton-mileage per locomotive varies between 290 and 3386; the two greatest averages, 2479 and 2209, being made at the two mines having the longest average hauls of 6217 and 6087 feet respectively. Of the two mines that lead in production one shows

TABLE 5

MAIN LINE HAULAGE FOR EIGHTEEN MINES

Group of Mines Producing between 1500 and 3000 Tons Daily

Mines	Ave. Daily Tonnage	No. Years in Oper.	Mine Car		Loco.		No. Partings	Ave. Dist. Haul. feet
			Empty Wt. tons	Coal Wt. tons	No.	Wt.		
1	2200	15	1.25	3.20	3	12-ton	5	3500
2	2600	14	1.00	3.05	2	14-ton	8	4000
3	2500	9	1.50	4.25	2	12-ton	10	4025
4	1800	12	1.45	3.25	2	13-ton	7	2700
5	2250	15	1.43	2.25	3	10-ton	10	4400
6	2200	17	1.00	2.40	2	10-ton	7	5000
7	1800	17	0.75	2.00	2	10-ton	6	5000
8	2500	22	0.70	3.00	3	10-ton	7	3750
9	1700	15	*	2.75	2	12-ton	4	2700
10	2500	4	1.05	2.90	3	10-ton	8	1950
11	1770	20	*	2.20	3	12-ton	5	5280
12	2200	20	*	2.25	3	12-ton	5	6600
13	1500	15	*	2.00	2	13-ton	5	6000
14	2000	15	*	2.50	3	15-ton	6	7000
15	3000	20	1.50	3.00	4	13-ton	11	6000
16	1700	31	1.50	3.00	3	13-ton	7	4500
17	1800	15	1.15	2.70	3	10-ton	6	5100
18	1600	16	1.10	3.00	3	10-ton	6	3500
Ave.	2100	16	1.18	2.78	3	12-ton	6	4500

*Empty car weight not available. Total ton-miles per loco. approximately 1.81 times ton-miles coal.

the greatest average daily mileage per locomotive while the other shows the least. It is interesting to note that Mine B, having the greatest production, puts the least average duty in total ton-miles per day upon its locomotives, but at the same time puts both extremes of such duty upon them. This mine has also the fewest ton-miles of coal per locomotive per day.

TABLE 5 (CONTINUED)

MAIN-LINE HAULAGE FOR EIGHTEEN MINES

Group of Mines Producing between 1500 and 3000 Tons Daily

Mines	Ave. Cars per Trip	Ave. Trips per Day	Ave. Cars per Loco. per Day	Ave. Tons Coal per Loco.	Ave. Ton-Miles Coal per Loco.	Ave. Ton-Miles per Loco.	Ave. Loco. Miles per Day
1	15	16	240	700	465	750	20
2	18	24	430	1300	1000	1670	36
3	20	15	300	1250	950	1620	23
4	20	15	300	900	460	690	15
5	20	17	340	750	600	1350	28
6	23	20	460	1100	1000	1830	38
7	22	20	440	900	850	1500	38
8	18	16	280	840	600	900	23
9	18	16	280	850	440	*	16
10	12	24	280	840	310	510	18
11	16	17	270	600	600	*	34
12	20	16	320	700	900	*	40
13	16	20	320	650	740	*	45
14	17	16	270	670	900	*	42
15	15	16	250	750	850	1700	36
16	12	16	190	570	490	980	27
17	22	10	220	600	580	1080	20
18	10	18	180	540	360	620	24
Ave.	17	17	300	800	670	1320	29

*Empty car weight not available. Total ton-miles per loco. approximately 1.81 times ton-miles coal.

TABLE 6

PERFORMANCE OF FIVE 15-TON MAIN-LINE LOCOMOTIVES IN A LARGE ILLINOIS MINE

For One Shift

Locomotive	(a)		(b)		(c)	
No. Trips	14		13		15	
Ave. No. Cars per Empty Trip	18		18		18	
Ave. No. Cars per Loaded Trip	19		18		18	
Total Loads	275		242		292	
Total Tons Coal	1133		997		1203	
Ave. Distance Hauled	4850		3700		4950	
Ton-Miles Coal	1040		700		1130	
Locomotive Miles	26		18		28	
Analysis of Time	Min.	Per Cent	Min.	Per Cent	Min.	Per Cent
Running Time on Main Line	197	43	197	43	198	44
Loaded	102		94		105	
Empty	95		103		93	
Switching Time	102	22	87	19	92	20
Motor Run	24		22		28	
Empty Run Around	27		20		23	
Inside Parting	51		45		41	
Total Running Time	299	65	284	62	290	64
Total Delays	161	35	177		163	
Delays at Shaft Bottom						
Blocked by Loads	87		79		52	
Waits for Empties	15		19		21	
Delays, Inside Partings						
Waits for Loads	59		36		90	
Repairs	..		43		..	
Total Operating Time	460	100	461	100	453	100

TABLE 6 (CONTINUED)

PERFORMANCE OF FIVE 15-TON MAIN-LINE LOCOMOTIVES IN A LARGE ILLINOIS MINE
For One Shift

Locomotive	(d)		Ave.		(e)*	
No. Trips	14		14		14	
Ave. No. Cars per Empty Trip	23		19		16	
Ave. No. Cars per Loaded Trip	23		19		15	
Total Loads	543		288		208	
Total Tons Coal	1413		1186		857	
Ave. Distance Hauled	4750		4562		1500	
Ton-Miles Coal	1270		1035		240	
Locomotive Miles	25		24		8	
Analysis of Time	Min.	Per Cent	Min.	Per Cent	Min.	Per Cent
Running Time on Main Line	189	44	195	43	118	26
Loaded	98		100		68	
Empty	91		95		50	
Switching Time	92	21	93	21	55	12
Motor Run	34		27		....	
Empty Run Around	24		24		46	
Inside Parting	34		43		9	
Total Running Time	281	65	288	64	173	38
Total Delays	150		163		278	
Delays at Shaft Bottom						
Blocked by Loads	90		77			
Waits for Empties	23		20		201	
Delays, Inside Partings						
Waits for Loads	37		56		77	
Repairs	..		10			
Total Operating Time	431	100	451	100	451	100

* Locomotive (e) does relay duty.

TABLE 7

GATHERING HAULAGE IN EIGHT TYPICAL LARGE ILLINOIS COAL MINES

Mine	Ave. Tons Daily	Locomotive			No. Mules	No. Partings	Approx. Dist. Hauled to Partings			Cars per Trip to Partings			Cars per Day to Partings		
		No.	Wt.	Kind			Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
B[1]	5200	12 11	8-ton 6-ton	Reel and Trolley	0	8	2200	600	1137	6	6	6	190	85	146
C	4500	12	8-ton	Storage Battery	0	12	1900	800	1000	8	2	7	80	35	69
D	5000	9 6	6-ton 8-ton	Reel and Stor. Bat.	5	14	2100	800	1366	14	2	9	200	40	107
E	3800	0	..	....	17	4	1300	700	1055	3	2	2	375	180	294
F	3600	16	6-ton	Reel and Trolley	0	9	2000	800	1389	15	11	14	126	42	86
G	2600	14	6-ton	Reel and Trolley	0	6	1700	700	1036	8	2	5	225	20	138
H	3400	14	..	Storage Battery	0	6	1800	900	1150	10	5	8	280	80	176
I[2]	4000	14	6-ton	Dry Battery	3	8	2000	L.1100	L.1379 M. 700	8	L. 8	L. 8 M.1	240	L.96	L. 178 M. 90

[1] In this mine one locomotive gathers to the shaft bottom. Its performance is included in Table 10, Main-Line Haulage.

[2] Locomotives gather exclusively to seven partings—mules exclusively to one parting.

TABLE 7 (CONTINUED)

GATHERING HAULAGE IN EIGHT TYPICAL LARGE ILLINOIS COAL MINES

Mine	Tons Coal per Day to Partings			Tons Coal per Loco. or Mule			Ton-Miles, Coal per Loco. or Mule			Total Ton-Miles, per Loco. or Mule			Total Daily Mileage per Loco. or Mule			No. Miners per Parting			No. Machines per Parting		
	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
B[1]	820	360	617	300	170	228	74	26	45	141	50	86	5.6	2.1	3.6	71	29	57	7	2	5
C	400	175	327	400	175	340	144	30	66	259	54	119	7.2	1.5	3.9	34	16	27	3	1	2
D	700	140	375	L. 350 M.180	225 140	300 150	L. 139 M. 36	48 21	85 .29	L. 235 M. 60	80 36	144 49	L. 6.4 M.10.9	3.0 6.0	4.4 8.4	50	10	28	..	..	..
E	870	410	675	230	90	159	48	20	31	102	43	66	14.8	7.6	11.3	121	55	91	5	3	4
F	570	189	383	270	189	215	73	38	54	138	72	102	10.6	4.5	6.9	51	19	36	5	2	3
G	742	66	455	330	66	196	58	14	37	123	29	78	7.1	3.1	4.2	66	8	38	4	1	3
H	910	260	572	325	87	245	97	25	54	193	49	107	7.5	3.0	4.3	93	24	56	6	3	5
I[2]	720	L. 288	L. 535 M. 270	288	240	L. 267 M. 90	98	L.55	L. 70 M.12	189	L.106	L.135 M.23	8.2	L.4.6	L. 5.8 M.8.0	60	24	43	5	2	4

[1] In this mine one locomotive gathers to the shaft bottom. Its performance is included in Table 10, Main-Line Haulage.

[2] Locomotives gather exclusively to seven partings—mules exclusively to one parting.

TABLE 8

GATHERING HAULAGE IN SEVENTEEN TYPICAL ILLINOIS COAL MINES

Mine No.	Ave. Daily Ton-nage	No. Men		No. Ma-chines	No. Mules	Locomotives			No. Part-ings
		in Entries	in Rooms			No.	Wt.	Kind	
1	2200	32	178	21	0	11	6-ton	Reel	5
2	2600	26	154	17	0	13	6-ton	Reel	8
3	2500	70	170	22	0	14	6-ton	Reel	10
4	1800	58	130	17	0	8	6-ton	Reel	7
5	2250	66	217	15	25	..	.....	....	10
6	2200	40	164	17	.. 5	8 ..	5-ton	St. Bat.	7
7	1800	40	164	17	.. 2	8 ..	6-ton	St. Bat.	6
8	2500	50	190	18	 17	1 3 ..	6-ton 6-ton	St. Bat. Reel	7
9	1700	30	113	11	12	..	.....	....	4
10	2500	54	349	..	0	14	5-ton	St. Bat.	8
11	1770	49	132	18	24	..	.....	....	6
12	2200	41	177	22	28 1	.. ..	....	....	5 1
14	2000	..	300	..	.. 12	4 ..	5-ton	St. Bat.	8
15	3000	23	252	11	0	12	5-ton	St. Bat.	6
16	1700	16	200	2	.. 2	6 ..	5-ton	St. Bat.	7
17	1800	46	125	20	 4	2 5 ..	....	St. Bat. Reel	6
18	1600	..	...	....	20	..	.....	....	6

TABLE 8 (CONTINUED)

GATHERING HAULAGE IN SEVENTEEN TYPICAL ILLINOIS COAL MINES

	Mine No.	Ave. Dist. Haul. feet	Ave. Car Trips	Ave. Trips per Day	Ave. Cars per Loco. or Mule	Ave. Tons Coal per Loco. or Mule	Ave. Wt. Tons Coal per Car	Ave. Ton-Mi. Coal per Loco. or Mule	Ave. Ton-Mi. per Loco. or Mule	Ave. Loco. or Mule-Mi. per Day
	1	L. 1500	6—	11	63	200	3.20	56.8	102.0	6.24
	2	L. 1100	8+	8	67	200	3.05	41.7	69.8	3.34
	3	L. 1650	5	8	40	170	4.25	53.1	90.6	5.00
	4	L. 850	7	10	70	225	3.25	36.2	68.8	3.22
	5	M. 800	1½	27	40	90	2.25	13.6	30.9	8.18
	6	L. 1000	6+	14	85	200	2.40	37.9	70.8	5.30
		M. 500	3	15	45	110	2.40	10.4	18.9	2.84
	7	L. 1000	7+	14	100	200	2.00	37.9	66.4	5.30
		M. 500	3	16	48	100	2.00	9.5	16.3	3.03
	8	L. 900	7	10	70	200	3.00	34.1	52.5	3.41
		M. 900	1–2	25	32	100	3.00	17.0	24.6	8.53
	9	M. 1000	3	17	50	140	2.75	26.5	49.7	6.44
	10	L. 1200	6+	10	62	180	2.90	40.8	70.4	4.54
	11	M. 1000	1	32	32	70	2.20	13.2	24.8	12.11
	12	M. 800	1	35	35	40	2.25	6.1	11.4	10.60
		M. 650	1	40	40	75	2.25	9.2	17.2	9.85
	14	L. 1200	7—	12	80	200	2.50	45.4	82.2	5.45
		M. 800	2	20	40	100	2.50	15.1	28.3	6.06
	15	L. 1100	6—	14	83	250	3.00	52.1	103.9	5.83
	16	L. 1000	6—	15	87	260	3.00	49.2	98.7	5.68
		M. 700	1	24	24	70	3.00	9.3	18.8	6.36
	17	L. 1800	7+	11	80	210	2.70	71.5	136.3	7.50
		M. 1300	1	32	32	85	2.70	20.9	39.0	15.75
	18	M. 900	1	27	27	80	3.00	13.6	23.7	9.20
Ave. Performance	109 Loco.	1227	..	11.05	71—	204.9	3.04	46.94	84.98	5.21
	54 Reel-trolley Loco.	1341	..	9.30	61	197.0	3.39	49.26	86.80	5.10
	55 St. Bat. Loco.	1115	..	12.76	80+	212.4	2.70	44.67	83.20	5.30
	152 Mules	869	..	27.36	36	82.5	2.18	13.60	25.30	9.05

Somewhat similar data are given in Table 5 for 18 mines having a variation in production from 1500 to 3000 tons per day. Most of these mines, being older than those listed in Table 4 and therefore having mine cars that are generally of less capacity, have lower ton-mileages.

Table 6 has been prepared from data taken in one of the largest coal mines of Illinois to show the average daily performance of the main-line locomotives. These data cover one full shift of eight hours. The average distance traveled by a locomotive per round trip was 1.72 miles. Each locomotive was on duty approximately 94 per cent of its full shift, and an analysis of its actual operating time is given. Thus locomotive (a) was on duty 460 minutes or during 96 per cent of its 8-hour shift, but of this time it actually operated only 299 minutes or 65 per cent of the 460 minutes. Four kinds of delays consumed 161 minutes of this locomotive's time and the average delay per locomotive per shift was practically 2.72 hours.

24. *Performance of Gathering Locomotives.*—Table 7 covers the data on gathering haulage for the same mines as, and in a manner similar to, Table 4 for main haulage. Table 8 similarly covers seventeen of the mines in Table 5. Owing to the constantly changing distances that cars are hauled in gathering from the same territory, it was impossible in the time available to obtain accurate data for each car moved during the period when the study was made in each mine, but a distance from a central point in the panel to the parting was assumed as the average travel for the cars gathered from the given panel, and the average weight of coal per car was also assumed for the mine during the given period. While these assumptions may not give exact results for any given day, they probably represent the average operating conditions of any given mine and are of value in comparing the performance of locomotives in different mines and in different sections of the same mine.

Gathering is performed by locomotives exclusively in five of the selected eight large Illinois coal mines, by mules exclusively in one of these mines, and by both locomotives and mules in two mines. These eight mines utilize for gathering haulage 108 locomotives and 25 mules.

Improvements in reel and crab locomotives permit their use in even the most difficult working places.

The average distance covered by main-line haulage in these eight typical mines is 4555 feet, while the average distance traveled in gathering in these same mines is but 1141 feet, or approximately one-fourth the main haulage travel. The sizes of trips in the two stages of haulage are as 7 cars in gathering to 19 cars in main haulage. In main-line haulage a locomotive averages 31.3 miles per day, whereas in gathering it averages but 4.8 miles. In total ton-mileage per locomotive the figures for the two classes of haulage are as 111 in gathering to 1985 in main haulage, or about as 1 to 18.

As the activities of coal mining continually alter underground workings, the tables must be accepted as statistically accurate for a relatively short period only, and only for the dates upon which the data were secured. The method of diagramming and listing the data for each of the mines is illustrated by giving the diagrams and tables for Mine A, having one-stage haulage, and for Mine D, having two-stage haulage.

25. *Details of Haulage Performance in Typical Illinois Mines.*—The detailed methods of representing the workings diagrammatically and of tabulating the haulage data used in compiling Tables 4 and 7 are given for two mines only—in Table 9 for Mine A, and in Tables 10 and 11 for Mine D. In Mine A, cars are hauled directly from the rooms to the shaft bottom by one set of locomotives, while in Mine D there is a distinction as to gathering and main-line haulage.

The following data regarding the handling of cars from the face to the shaft bottom will supplement the shaft-bottom data given in connection with Table 3.

Mine A

The daily production is 4500 tons. Each mine car weighs 2780 pounds empty, and holds four tons of coal, and there are 474 cars in the mine. Approximately equal amounts of coal reach the shaft bottom from the north and south sections of the mine, and the cars are brought directly from the working face to the shaft bottom by the same locomotives that gather the coal and operate on the main line. All empties are similarly hauled from the shaft bottom directly to the workings. It is believed that the system of gathering directly to the shaft bottom involves fewer delays.

Although the shaft was sunk at the approximate center of the original property the later development of the mine has been such that

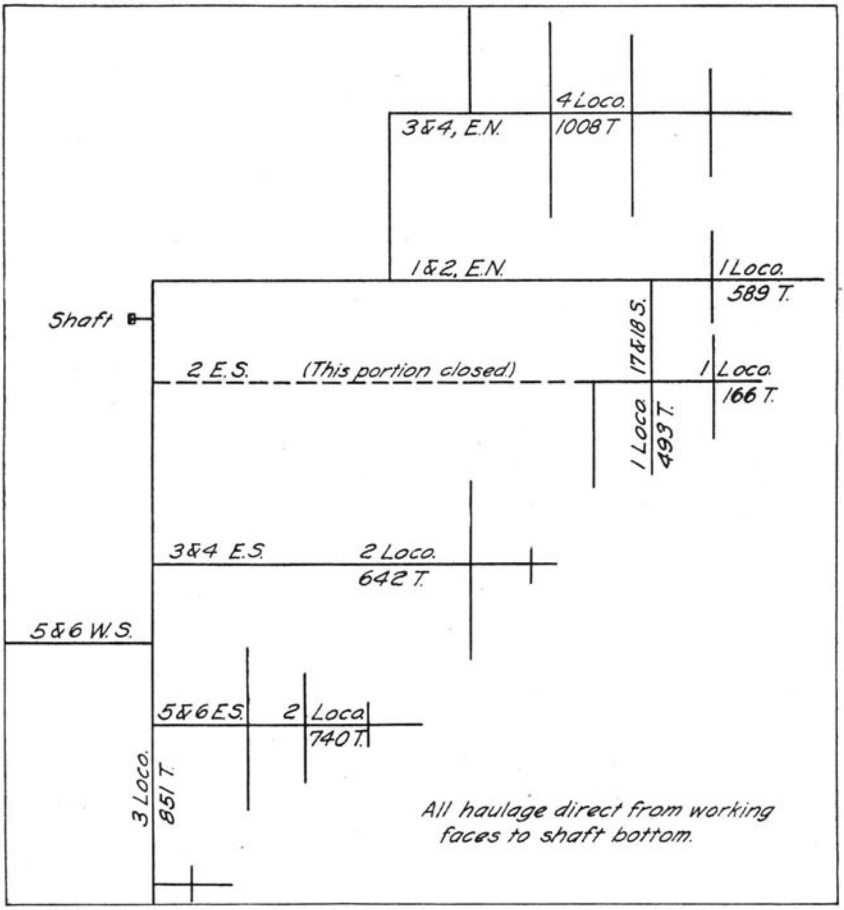

FIG. 25. HAULAGE DIAGRAM—MINE A

at present the shaft is near one side of the operating portion of the mine thus giving a rate of advance for the haulage roads about double that for a centrally located shaft. Fig. 25 is a diagrammatic sketch of the haulage roads in Mine A.

The main-haulage road is double track for 2500 feet in each direction from the shaft, north and south, so that there is no interference of incoming and outgoing trips. Adequate pass-partings also permit trips to pass conveniently in the cross-entries. Switch throwers

TABLE 9

HAULAGE—MINE A

Territories	Locomotives		Approx. Dist. Hauled	No. Cars per Day	Tons Coal per Day	Ton-Miles Coal per Loco.	Total Ton-Miles per Loco.	Daily Mileage per Loco.	No. of Men in	
	No.	Kind							Entries	Rooms
3 and 4, ES....	2	Reel and Trolley	6230	60	242.98	387.20	690.85	19.39	6	52
			7000	21	83.30					
			6300	79	316.20					
5 and 6, ES....	2	Reel and Trolley	5550	78	313.90	403.74	720.36	21.88	10	48
			6600	33	123.45					
			5640	75	302.60					
Main S, & 5 and 6, WS...	3	Reel and Trolley	6700	25	95.30	307.21	548.13	15.51	18	55
			5000	74	300.10					
			5300	74	298.85					
			7300	40	156.60					
2 ES.........	1	Reel and Trolley	8230	49	195.00	409.05	729.83	24.61	4	15
			7800	18	71.15					
17 & 18 S.-2 ES	1	Reel and Trolley	7000	123	492.80	653.33	1165.68	37.12	0	38
1 and 2, EN ...	1	Reel and Trolley	6900	77	310.35	769.95	1373.75	41.84	0	28
			6825	61	243.05				0	28
			7500	9	35.35				4	0
3 and 4, EN ...	4	Reel and Trolley	7075	88	366.80	353.85	631.34	20.57	0	25
			7760	41	166.50				0	13
			7900	17	67.30				10	0
			7375	85	340.65				0	27
			8150	17	66.55				8	0
Averages..	.....	......	6707	..	....	410.80	732.95	22.50	..	..

are stationed at main junction points and extra flagmen are placed as required. The locomotives in this mine are combined trolley and storage-battery locomotives, and, while the greater part of the haulage is done by using current from a trolley wire, current from the batteries enables the locomotives to reach the working faces. This system is here held preferable to the use of reel locomotives in that it reduces delay in changing from trolley service and lessens the peak loads on the power circuit. Each locomotive averages daily seven trips of from 6 to 14 cars each. The grades in the room are nearly level and about 95 per cent of the empty cars are left by the locomotives at the room necks, but the loaded cars are gathered from the faces by the locomotives. The average haul of a locomotive is 6707 feet.

Mine A has the same daily production as Mine C in which the haulage is divided into two stages. For Mine A the average total ton-miles per locomotive is 733. In Mine C the average total ton-miles per locomotive per day in gathering is 119 and in main haulage is 1624, and the general average for all locomotives is 420. Similarly, the respective total of ton-miles for gathering haulage and main haulage in Mine D (which has a daily production of 5000 tons) are 144 and 2047, and the average for all locomotives, 544. The average data for the eight large mines in Tables 4 and 7 are respectively 111 and 1985 with a general average for all gathering and main locomotives of 497. These statistics would indicate that the duties imposed upon a locomotive in a single-haulage-system mine are heavier than those imposed on a locomotive in a double-haulage-system mine. This may be explained by the fact that the weight and capacity of all locomotives in the two-stage-haulage mines will average less than in mines having single-stage haulage.

Mine D

The daily production is 5000 tons. The mine cars weigh 2400 pounds empty and hold 3.50 tons of coal. The mine is developed uniformly, two-fifths of the production coming from the eastern section and three-fifths from the western. Two main-line locomotives operate in each section, each locomotive serving from three to five partings and averaging 26 trips of 15 cars each per shift of eight hours. The average length of main haul is nearly one mile. The system of train despatching minimizes the time lost on the partings, as the haulage-boss at the shaft bottom keeps in telephonic communication with a man stationed at each parting and, whenever a trip is reported as made up there, sends a locomotive to that point.

Tables 10 and 11 give the data obtained by a detailed study of Mine D, and Fig. 26 is a skeleton diagram of the haulage system at the time the observations were made. All main-line haulage is done by four trolley locomotives.

Table 10 gives the territories covered in gathering by fifteen locomotives and five mules. Two of the partings are served by both locomotives and mules. One point brought out by this tabulation is that although mules do not handle as great tonnage per day as the locomotives, they travel considerably farther. The mules in this mine average 8.5 miles of travel daily whereas the locomotives average but 4.4 miles.

Mine B

One-third of the production comes from the north side and two-thirds from the south side of the mine. Four 15-ton main-line locomotives haul an average trip of 15 to 16 cars over an average distance of 4630 feet, making slightly more than two round trips per hour. One 15-ton relay locomotive operates between two main partings and forms part of the main haulage system. Two other locomotives not only haul to the shaft bottom an average of six trips of eight cars each per day, but also gather the cars from the working faces. The grade on the main haulage road is generally in favor of the loaded cars and in some instances the grade is so steep that the loaded trips must be limited in size so that they can be safely handled by the locomotives.

The empty cars are taken to the working faces and the loaded cars obtained there by the gathering locomotives. In some of the rooms 4.5 per cent grades are encountered, thus taxing the gathering locomotives. The average capacity of the gathering partings is thirty cars, while the average main-line trip is 17 cars. Hence a supply of empties can be left on the gathering partings between main-line trips and the gathering locomotives need not wait for the return of the main-line trip before returning to the room faces.

Mine C

The mine is divided into four separate, nearly equal sections served by three main-line trolley locomotives, one hauling from each of two sections and one handling the tonnage of the other two sections.

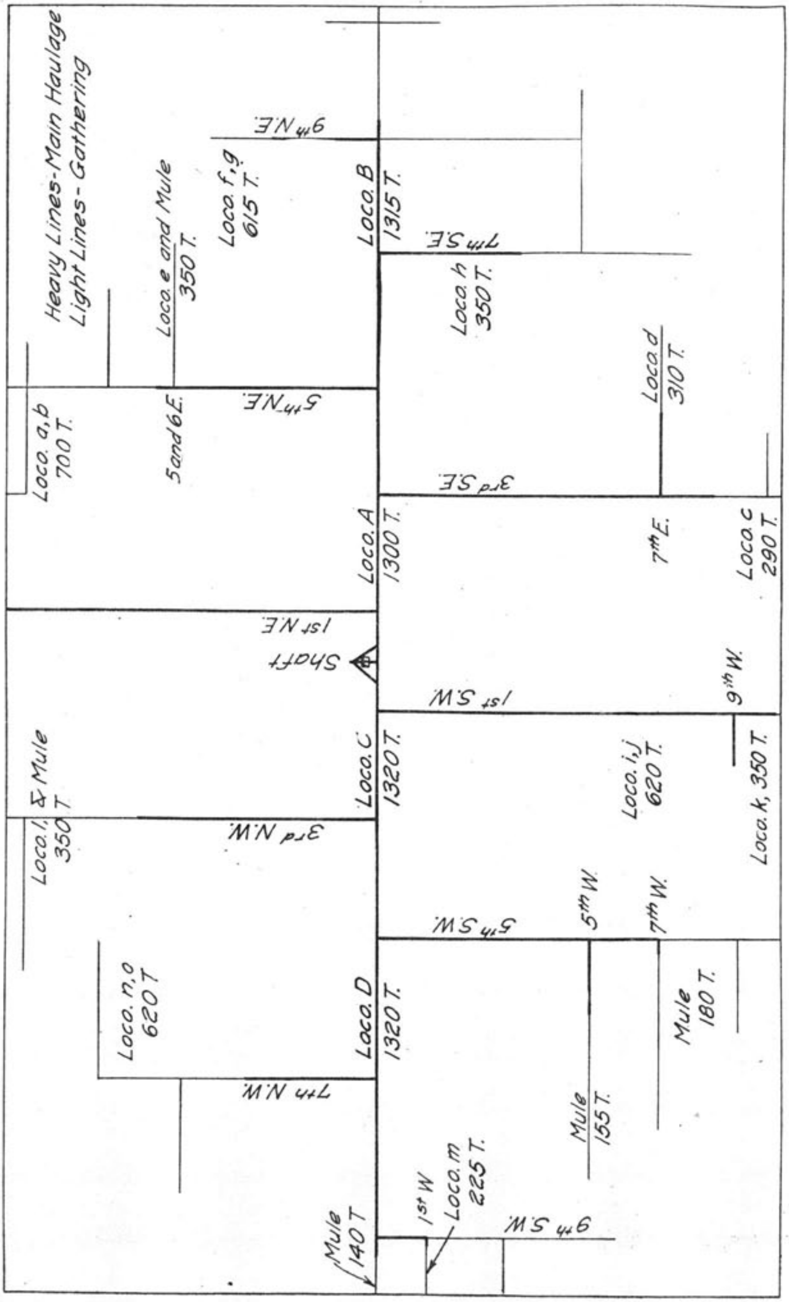

FIG. 26. HAULAGE DIAGRAM—MINE D

TABLE 10. GATHERING HAULAGE—MINE D

Partings	Mules	Locomotives			Approx. Dist. Hauled Feet	Cars per Trip	Trips per Day	Cars per Day	Tons per Day	Ton-Miles Coal	Total Ton-Miles	Loco. Mi. or Mule Mi. per Day	No. Men in	
		No.	Wt.	Kind									Entries	Rooms
1st N. E.		(a) 1	6-ton	Reel	1500	12	8	96	700	95.4	160.8	4.55	0	24
		(b) 1	8-ton	St. Bat.	1250	13	8	104		86.2	145.3	3.79	10	16
3d S. E.		(c) 1	6-ton	St. Bat.	1800	11	8	80	290	98.9	166.7	5.45	0	22
7 E, 3d S. E.		(d) 1	6-ton	Reel	1400	12	8	90	310	82.2	138.6	4.24	0	24
5 & 6, 5th N. E.	1	(e) 1	8-ton	St. Bat.	1400	8	8	60	350	55.7	93.9	4.24	6	10
		....	....	....	800	2	20	40		21.2	35.7	6.05	4	6
9th N. E.		(f) 1	6-ton	St. Bat.	1000	14	8	105	615	69.6	117.3	3.03	6	22
		(g) 1	6-ton	Reel	1700	9	8	70		78.9	133.0	5.15	10	8
7th S. E.		(h) 1	8-ton	St. Bat.	1200	13	8	100	350	79.5	134.0	3.64	0	26
1st S. W.		(i) 1	6-ton	Reel	1500	11	8	85	620	84.5	142.5	4.55	4	18
		(j) 1	6-ton	Ree	1500	12	8	95		94.5	159.3	4.55	6	18
9W, 1st S. W.		(k) 1	6-ton	St. Bat.	2100	13	8	100	350	139.2	234.7	6.36	8	18
3d N. W.		(l) 1	6-ton	Reel	1500	13	8	100	350	99.4	167.6	4.55	10	16
	1	....	....	....										
7W, 5th S. W.	1	....	....	....	800	2	25	50	180	26.5	44.7	7.58	4	10
5W, 5th S. W.	1	....	....	....	1200	2	24	45	155	35.8	60.4	10.90	2	10
1W, 9th S. W.		(m) 1	8-ton	St. Bat.	1200	8	8	60	225	47.7	80.4	3.64	8	8
Main W.	1	....	....	....	1200	2	20	40	140	31.8	53.6	9.08	6	4
7th N. W.		(n) 1	8-ton	St. Bat.	1800	10	8	80	620	95.4	160.8	5.45	8	12
		(o) 1	8-ton	St. Bat.	1100	13	8	100		72.9	122.9	3.34	4	22

Letters in parentheses refer to territories indicated on the diagram of this mine, Fig. 26.

TABLE 11

MAIN-LINE HAULAGE — MINE D

Partings	Locomotives			Approx. Dist. Haul'd Feet	Cars per Trip	Trips per Day	Cars per Day	Tons per Day	Ton-Miles Coal	Total Ton-Miles	Mileage per Loco.
	No.	Wt.	Kind								
1st N. E.				4400	14	14	200	700			
3d S. E.	(A) 1	15-ton	Trolley	5700	10	8	80	290	1157	1943	51.6
7 E, 3d S. E.				5300	14	7	90	310			
5th N. E.				4800	14	8	100	350			
9th N. E.	(B) 1	15-ton	Trolley	5200	15	12	175	615	1186	1996	48.7
7th S. E.				5400	15	7	100	350			
1st S. W.				4500	23	8	180	620			
9W, 1st S. W.	(C) 1	12-ton	Trolley	4500	16	7	100	350	1081	1837	37.7
3d N. W.				4000	14	8	100	350			
7 W, 5th S. W.				5700	15	4	50	180			
5W, 5th S. W.				5500	16	3	45	155			
1 W, 9th S. W.	(D) 1	15-ton	Trolley	5900	16	4	60	225	1381	2411	56.7
Main W.				6900	14	3	40	140			
7th N. W.				5500	15	12	180	620			

Letters in parentheses refer to territories indicated on the diagram of this mine, Fig. 26.

Grades are uniformly level. Each of the four sections of the mine has a separate current of air and a minimum number of self-closing, double doors. No trappers are employed.

Mine E

The two main sections of the mine furnish nearly equal production and two main-line locomotives operate in each section. In the northeast section the round trip averages over 3 miles.

Mine F

The east and west sections are laid out symmetrically and have about equal productions. One main-line locomotive operates in each section.

Mine G

The mine has two sections, east and west, which produce about equal amounts. There is one main-line locomotive for each section.

Mine H

There are two partings in the east workings and three partings in the west workings, each set of partings being served by one main-line locomotive.

Mine I

The eight partings in this mine are so grouped into pairs that all main haulage is performed by four trolley locomotives. An average of 500 tons of coal goes to the shaft bottom daily from each parting. Gathering in this mine is mixed, but not in the sense that both locomotives and mules are used in the same territories. Instead, 3 mules are used exclusively in gathering to one parting, while 14 locomotives handle the remaining seven-eighths of the mine. The mules haul but one car per trip.

26. *Mine Cars.*—In Illinois as in other coal-mining states many kinds of cars are in use even in mines of a single district, worked in the same seam, and with all conditions essentially common. When a particular type of pit-car is once adopted it is a difficult and expensive process to modify that type. It may thus happen that two neighboring mines, perhaps of common ownership, may be equipped with unlike cars and that in consequence the haulage and hoisting arrangements are so dissimilar that any interchange of cars for convenience or emergency is impossible. The regularity of the pitch, the thickness and the depth of the seam, the nature of the roof, the type of haulage system to be used, and the extent of the mining property all have weight in determining the design of mine cars.

Car Body

Formerly all coal-mine cars were constructed with wooden bodies, steel and iron being used in the wheels and axle and for stiffening the body. Indeed there are still some operators who, with strong arguments therefor, retain those wooden cars—and there are some mines which have both wooden and steel cars in service. General practice, however, is restricting usage to either type of car exclusively in any one mine, and the all-steel car is coming more generally into use and has now wholly superseded the wooden car in many mines. There are several reasons for this change.

One desideratum in the design and construction of a serviceable car is the utmost stiffness and strength in the trucks or running gear. The axles should always be in true alignment, and, since these members are held in their relative positions by their attachment to the floor of the car, stiffness in the car floor is of great importance. Without this rigidity there is a tendency for the car-wheels to climb the rails, frequently with derailment. The greatest stiffness is afforded by steel floors, and the all-steel car is much stiffer in this respect than is the car with a steel bottom but with wooden sides and ends.

Wreckage of mine cars occurs often at derailments. Experience proves that the all-steel car is the more resistant to injury or deformation, hence is less likely to be injured in such accidents and causes less delay to haulage. On the other hand, repair work on the steel car is frequently the more difficult and expensive.

There is no fixed ratio between the relative weights of the two general types of cars. Much depends upon the design, which in turn depends upon the methods used in dumping the loaded cars. A car used with rotary dumpers may be lighter in weight than one of equal capacity used with automatic-dumping cages. A steel car will be slightly less in width than an equivalent wooden car, this affording more clearance along the sides. The superior rigidity of the steel car causes it to travel more smoothly. Consequently there is less spillage of coal along the roads and loads may therefore be topped higher than is practicable with wooden cars. A steel car ordinarily has a longer life than a wooden car, but this feature is considerably offset by its greater initial cost. The expense of construction and upkeep may be less for steel cars than for wooden cars when the figures are distributed to cost per ton of coal ultimately handled per car.

Truck

A car truck comprises two axles with their bearings. Strength and minimum weight are prime factors in the design of the ideal truck, but frequently an axle is too small to withstand its imposed duty.

Recently the outside-journal bearing, similar to that used on railway cars, has been successfully used on heavy steel coal cars for slope or drift mines. These journals possess merit for such service; yet the spragging of such cars is difficult and hand brakes become necessary, thus rendering the cars poorly adapted to service in self-dumping cages.

Wheel-Base

The length of wheel-base in Illinois is ordinarily between 16 and 30 inches, the maximum being 42 inches. A 24-inch wheel-base is general for a car 7 to 8 feet long, and a 30-inch wheel-base for a car 10 feet long; while, when short turn-outs are necessary, a shorter wheel-base is used. An advantage of the short wheel-base is the greater ease with which a car may be re-railed, owing to a more easily balanced load. The increase of a couple of inches between axles may add many pounds to the weight lifted by the miner in re-railing a car. A long wheel-base is generally conducive to easy running and minimum derailments from cars climbing the rail.

Wheels

The car wheel should have as great a diameter as possible considering the distance between roof and rail and the capacity of the car. The greater the diameter of the wheel the less is the power required to move the car, but the net load carried may be less. The diameters used in Illinois vary from 14 to 20 inches. The tread of the wheel, to provide the best service, should be of chilled steel while the angle between the flange and the tread is approximately 100 degrees. Both plain and roller bearings are used extensively. Wheels are now often self-oiling regardless of the type of bearing, and the cost of lubrication is a feature that cannot be lightly ignored.

Bumpers and Couplings

In designing bumpers two factors control: the safety of the coupler, and the greatest mechanical efficiency. Thick, round, single bumpers with a single link-and-pin coupling seem to be most generally used in this state. Their advantages are that cars do not become locked on curves and that less slack is found between cars when a trip is starting or stopping. The twin-bumper car is also used in Illinois. The type of coupling used with the twin bumper varies. In some mines the gravity coupling has proved satisfactory under unusually severe conditions. Recent designs feature a spring drawbar with a link coupling that decreases the jerking of trips and the accompanying loss of coal. With this spring drawbar fewer cars are derailed at starting, trips require less power in starting, and the general wear and tear on the car is less. Partially offsetting these advantages are a greater initial cost and additional repair expenses.

Capacity of Mine Cars

The weight and capacity of a mine car are important items in connection with the handling of the car by men. If the cars are pushed to the face by the miners, the number of cars taken to the parting by the gathering locomotives is increased in proportion to the time saved by the locomotive in not having to run into the rooms. This time may amount to several hours per day and can be utilized by the locomotive in haulage on the entry.

If cars are taken to the faces by the locomotive they should have the maximum capacity for the given conditions as the time consumed in taking a single car to the face is no greater for a large than for a small car, and the larger the car the longer it remains in the room during loading. The largest car now used in Illinois contains about $5\frac{1}{4}$ tons.

Number of Cars Required

The number of cars in use in any mine is equal to the number of loaders plus a variable reserve. Although each man usually has a separate working place, two loaders generally work together in a room while the adjoining room is being undercut by a machine. Therefore, the car supply at the mine should include for each room where cars are being loaded one car in the process of being loaded and one in transit between the room and shaft bottom or drift mouth. In addition there should be a certain number of surplus cars on the shaft bottom or tipple landing and on the various partings, to prevent delays and to replace those undergoing repair.

The minimum empty-car reserve on the shaft bottom for each main-line section of the mine should be not less than the average number of cars per trip for that section. For instance, if there are two main-line locomotives hauling to the shaft bottom, one from each side of the mine, delivering to two tracks on the shaft bottom, and if the average trip for each side of the mine is 15 cars, there should be storage space for at least 30 empty cars on the shaft bottom, so that the incoming locomotive may find an empty trip ready to couple to as soon as it has uncoupled from its loaded trip. Likewise to prevent delay on each of the partings there should be a trip of loaded cars ready for the locomotive as soon at it has uncoupled from its empty trip. As shown in Table 3, the empty-car reserve varies widely at different mines.

The factors that influence the number of cars required for a given daily output are: the car capacity, the length of haul, the system of haulage, and the method of operating the haulage system. The greater the capacity per car the fewer the cars to be hoisted per day for a given output, and the longer the haul the more cars will be required. Mechanical haulage should require fewer cars than mule haulage as the cars are moving more rapidly and usually cars of larger capacity are used.

An unnecessary reserve of cars is objectionable on account of the extra capital they represent. The average life of a mine car is five to eight years and, assuming cost of the cars as $160, about $20 per car must be charged off each year for a life of 8 years. According to Table 3, a car is loaded on an average 2.05 times per day and the average capacity is 3.64 tons per day. In a year, or 200 days, a car will handle 1492 tons. On this basis the mine-car depreciation charge is approximately 1.34 cents per ton of coal hauled. This does not include the cost of repairs but only the gross depreciation per car of $20 per year.

For a simple calculation consider a mine having four main partings of equal production which for a given day will supply an equal number of cars, say 300 each, or a total of 1200 cars for a mine producing between 4000 and 5000 tons. If the "turn" runs four cars per loader, 75 loaders will furnish 300 cars from each of four districts or 300 loaders will be required for the total. Consider one unit of this group, and assume that 75 loaders will produce 300 cars and that the parting is 5000 feet from the shaft bottom. Assume also one main locomotive under ordinary operating conditions, 16 trips of 19 to 20 cars each at the rate of one trip every half hour, on the basis of ten minutes running time each way and ten minutes for switching at the two terminal points, this being an easy operating schedule. Under favorable conditions a gathering locomotive should deliver at the parting 100 cars per day, assuming the same number of trips per day as for the main-line locomotives, a running time of 6 minutes, a switching time of 24 minutes, and 6 to 7 cars per trip. This is, however, considerably higher than the average Illinois gathering performance. At most mines four locomotives are required to handle 300 cars as assumed, operating on the same schedule with five-car trips, and gathering approximately 75 cars per day per locomotive. On a practical operating basis with a fixed running schedule of one trip every half-hour, the empty reserve on the parting is zero, as the times of arrival of main and gathering locomotives should be within a few minutes of each other, just as in the schedule operations of ordinary town or city trolley cars. The total empty reserve in such instances is held practically on the shaft bottom.

There should be some possible combination of the "turn" and the number of rooms per panel that will make it possible to determine the frequency of trips and the number of cars per trip for the most economical gathering schedule. Cars should be distributed at uniform intervals throughout the day. If the "turn" is to be 8 cars for two men then a trip every hour should be regularly established. The larger the car, the longer the time required for loading and the fewer the cars required for the "turn." If the car is of such capacity that a six-car "turn" gives the desired tonnage, a trip every 80 minutes will be adequate.

Standardization

With the object of bringing about more uniformity in design and construction, efforts have been made to establish acceptable standard specifications for a few of the main features of coal-mine cars. A committee of the American Mining Congress for The Standardization of Underground Transportation Equipment, coöperating with The Industrial Car Manufacturers' Institute, has recommended the following specifications for the design and construction of coal-mine cars:

(1) A track gauge of 42 inches should be adopted for all new coal-mining developments.

(2) The most desirable wheel-base is 42 inches.

(3) The overall length of a car-body should be three times the wheel-base, thus making the standard length 126 inches, or 10 feet 6 inches.

(4) Standardized automatic couplings, comparable to those of surface railways, should be used. For a car with 16-inch wheels the center of such a coupling should be 10 inches above the top of

rail, with a variation of 1 inch above to accommodate 18-inch wheels and of 1 inch below for 14-inch wheels.

Discussion of these features elicited the following statements: About 80 per cent of all new track-work in coal mines of this country is of 42-inch gauge. This gauge will fit all mine conditions and will accommodate any appropriate car-body. A 42-inch wheel-base is theoretically correct and practical; it minimizes derailment, increases speed possibilities, and tends to lengthen the life of cars.

Repairs

The expense of maintaining mine cars is not generally known; hence the following data upon this matter gathered by one large Illinois coal-mining company are of interest. During a period of eight months or 117 operating days there were 400 cars in service. The average weight of an empty car was 2000 and the average load of coal per car, 5000 pounds. The total tonnage hauled was 292 877, with the daily average per eight-hour shift, 2503. There were used 9279 board feet of oak, besides bolts and washers. At this mine one carpenter would finish all the repairs to a two-ton wooden car in from 8 to 16 hours. The average life of a car was 5 years.

27. *Track Construction.*—Proper track construction and maintenance are important in any haulage system, as the expected benefit from expensive rolling equipment may be offset by a poor track. In many mines the defects in track construction would be much more apparent if the track could be lifted out intact and reproduced in all its variations on the surface. In development work track of a temporary nature only is laid. In the rooms where track is intended only for locomotives with one or two cars moving at a slow speed light construction is used. But on the main-haulage track the construction should be designed for the heavier locomotives and longer trips of cars that are now generally used.

Gauge

The gauge of track has a direct bearing upon the capacity of coal-mine cars. A narrow gauge permits a longer wheel-base on sharp curves but as a rule the car is subject to more derailment. Gauges varying from 36 to 42 inches are common in Illinois bituminous mines. The maximum gauge in the state is 48 inches. Other conditions being equal, the wider the track gauge the wider may be the car and the greater its capacity. In low coal this is a pertinent factor. Good roof conditions permit wide gauges. Entries are usually driven 12 feet wide and the 42-inch gauge has proved well adapted to such entries.

Rails

Until a few years ago 40-pound rails on the main entries, 30-pound on the cross-entries, and 20-pound in rooms were considered adequate; but with the advent of larger cars, heavier locomotives and longer trips, the weight of rails and sizes of ties and spikes have increased considerably. Numerous large companies have adopted as standard not less than 50-pound rails for the main entries and 30-pound for rooms and cross-entries. In some instances 60- to 70-pound rails are used on main entries with excellent results. Where large cars and gathering locomotives are used 30-pound rails possess considerable advantage over 20-pound rails for rooms and cross-entries, as the repair cost for the heavier rail is but slightly more than that for the lighter, while the added initial expense—both for the material and labor—is usually justified by the rails lasting longer.

Ties

Timber ties of the following sizes are generally used: main entry, 5 x 6 inches; cross entry, 4 x 5 inches; rooms, 3 x 4 inches or 4 x 5 inches. Oak is used if obtainable, although considerable quantities of elm, hickory, and sassafras are consumed. Hewn ties with the bark removed are generally used, and are spaced 18 inches in entries and 36 inches in rooms. The sizes of spikes used are: for 40 or 50-pound rail, ½ x 4 inches; for 30-pound rail, ½ x 3½ inches; for 20-pound rail, ½ x 2½ inches.

Steel ties are used to a limited extent both for entries and rooms. Their advantages are:

(1) They afford additional height of from 2 to 4 inches above the rails, thus permitting the use of higher coal cars and heavier loading of low cars.

(2) The ties are lighter in weight and more easy to handle than timber ties, therefore are more readily laid and taken up.

(3) The rails being held by lugs the track is easily kept at a true gauge and the spreading of rails is prevented.

(4) Because of the less height of rail from the ground a derailment can be more readily remedied.

Switches

Switches may be classed under three general heads according to the method of operation:

(1) Ground track, in which the lever lies close to the ground and moves either parallel to or at right angles to the track.

(2) Switch stand, in which the lever moves either perpendicular to the track or rotates.

(3) Automatic or partly automatic, in which the lever is thrown by contact with a locomotive, or by motormen or trip riders without leaving the locomotives.

All switches for main haulage roads should be substantial and reliable. To avoid wrecks and to properly care for the rolling stock, the lead should be as long as possible and should be definitely calculated. Manufacturers of track equipment recommend a 4- to 6-foot switch-point to be used with a No. 4 frog, the length depending on the length of locomotive wheel-base. Some operators prefer the kick latch in place of the switch-point operated by the switch-stand. If the roads are kept clean the kick latch has some advantages on secondary haulage roads.

The cost of switches varies with the design. The following represents average requirement of material and labor and the costs will vary with their fluctuations. The materials will be: one No. 4 riveted frog with 6-foot switch-points; one switchstand with bridle and connecting rods complete; forty 5 x 6 inch ties; sixteen ½ x 4 inch spikes, and eight special bonds and wiring. The labor will include delivering material to place, cost of laying the switch and bonding.

If gathering motors are used, the room turnouts are similar to the main-line switches upon a smaller scale. Good practice at the larger mines demands the use of the maximum radius, which varies usually from 25 to 35 feet. These radii are very nearly those used with No. 2 and No. 2½ frogs. If it is desirable to carry the track along the rib it may be necessary to change the radius of the curve entering the room. It can readily be seen that it would be impossible to enter a room neck 10 feet wide with a turnout of 25-foot radius if the neck were driven at right angles to the entry.

A room switch costs much less than a turnout or parting switch because of the smaller size of the rail and its shorter length. The salvage value is greater because it is more quickly removed. Cast-steel frogs are used at present for secondary haulage and have proved entirely satisfactory, their chief advantage being their low initial cost, and their chief disadvantage the difficulty of holding the frog in place.

With mule haulage the switch is much simpler and consists of one frog-point, one straight rail, and one turn rail. The length of lead will vary between 8 feet 6 inches and 12 feet 6 inches, depending on the gauge and the wheel-base of the car. Empty cars enter rooms by being slewed over the open fixed point by the driver. On the return the loaded car is shunted to the entry road with little jar.

V. Underground Haulage Costs

28. *Cost Accounting.*—Copies of the cost-accounting sheets of sixteen well known companies were studied for the purpose of constructing a table that would show how the companies itemize their haulage costs but, owing to the lack of any uniformity in this practice, the tabulation proved impossible. Some companies maintain no special account for Haulage but place all wages for this branch of mining under General Expense. Companies frequently include haulage and hoisting under Transportation, with so few sub-items as to prevent analysis.

Cagers are charged by four companies to Haulage, by three to Hoisting, by five to General, by one to Transportation, and by one to Caging, while six companies do not carry this item. Four accounts place tracklayers under Haulage, six under General. Trappers are charged to Haulage by but one company, this occupation being usually charged to Ventilation or General. The only occupations that are uniformly charged to Haulage are switchmen, greasers and sand driers. Of the 13 companies that itemize trip riders, 11 consider them as chargeable to Haulage.

It is even more difficult to secure cost under the subdivisions of shaft-bottom haulage, main-line haulage, and gathering haulage—the three general divisions into which mine haulage may logically be divided and which are necessary for a satisfactory comparison of details. Hoisting and haulage are often combined. The hoisting cost is, however, small in comparison with the haulage cost and it is more nearly uniform for different mines than is the haulage cost.

29. *Standardizing Cost Accounts.*—The lack of uniformity in the accounting of coal-mining costs applies not only to haulage but to every other phase of the industry, as operating companies naturally object to the radical changes in bookkeeping necessary for the adoption of a universal system. Thus, close comparison of expenses and profits of companies operating under either similar or dissimilar natural or commercial conditions—a study that would yield informa-

tion of value in dealing with commercial and industrial problems—has been impossible.

The Committee on Standard System of Accounting and Analysis of Cost Production of the National Coal Association has prepared the following schedule of the natural subdivisions of the work in and around a coal mine:

1. Mine Office
2. Superintendence
3. Engineering
4. Mining
5. Timbering
6. Deadwork
7. Tracklaying
8. Drainage
9. Ventilation
10. Haulage and Hoisting
11. Dumping and Tallying
12. Preparation
13. Railroad Car Loading and Yard Expense
14. Power
15. Repairs to Buildings and Permanent Structures

This same committee explains that haulage and hoisting should be accounted as follows:

Generation and Transmission of Power

This item includes the proportion of expense of generating power chargeable to haulage and the construction and upkeep of transmission lines and haulage circuits.

Care and Maintenance of Equipment

This item covers:

(a) Hoisting and haulage engine repair parts, lubricants, packing and waste, and wages of hoisting engineer and mechanics employed in care and repair; hoisting and haulage ropes, cage repairs, and replacements; safety devices, guides, and sheaves.

(b) Care and maintenance of motors; when motor haulage is used, repair parts and labor of care and repair.

(c) Care and maintenance of pit-cars; labor and material used in keeping pit-cars in repair; new cars to replace wrecked or worn-out cars, and additional cars necessary to maintain output by reason of increasing length of haul after mine has reached its contemplated output capacity.

(d) Care and maintenance of live stock, harness, stable supplies, grain and hay, wages of stablemen and veterinary, clipping and shoeing, etc.

Conducting Transportation

This item includes wages of drivers, boss drivers, motormen, trip riders, couplers, cagers, pushers, oilers, trappers, switch throwers, jackmen, and that part of hoisting engineer's wages not charged to Maintenance and Repairs.

Maintenance of Way

This item includes repairing roads, cleaning roads, relaying track, also new ties, rollers for rope haulage, etc.

Under the head of Tracklaying the committee report says:

> "While track is immediately connected with and necessary for the transportation of coal to the shaft bottom, and hence a necessary item incident to Haulage, it has long been regarded as a significant item in the cost sheet, and should stand by itself. To this account should be charged rails, ties, spikes, and fastenings, and the labor of grading roads and tracklaying in advancing work. Repairs to track should be charged to Haulage and Hoisting under Maintenance of Way. Purchases of track material should be charged to Track Material Account, and as the material is taken into the mine it should be credited and charged Tracklaying."

The committee's explanation of the item Tracklaying (usually called Trackwork by operators) illustrates a common reason for disagreements between haulage costs as estimated by various companies. As noted above, rails, ties, etc. for advancing roads are charged under a separate item Track, while relaid track is a part of haulage under Maintenance of Way. If track is pulled out of an entry and used in a new entry is it to be considered relaid and chargeable to Haulage or as advancing work and chargeable to Tracklaying? This is merely an instance of the difficulty of defining any system of segregated items so clearly that it is not open to misinterpretation.

In its wartime collection of costs the Federal Trade Commission asked for haulage costs under the following heads:

Haulage:
- *Animal*
- *Mechanical*
- *Equipment Repairs*
- *Stable Expense*
- *Labor*
- *Supplies*
- *Total*

The following items in the Instructions for Compiling Coal-Mining Costs have direct bearing upon haulage:

Labor—Haulage.—This account shall include the wages of hoisting engineers, cagers (top and bottom), motormen, brakemen, trip riders, switchmen, couplers, greasers, spraggers, stable boss, drivers, sand dryers, and other labor employed to operate the haulage facilities other than standard gauge railroad equipment. Wages of employees, such as electricians, blacksmiths, trackmen, car and locomotive repair men, and men engaged in maintaining haulage equipment and tracks, shall be charged to Maintenance Account.

Maintenance and Repair.—This account shall include the cost of labor employed in repairing and maintaining (1) the tipple, powerhouse, tracks, and other mine structures; (2) mining machines, pumps, fans, boilers, engines, motors, locomotives, mine cars, and other mining equipment.

Feed and Other Stable Supplies.—This account shall include the cost to the operator of feed, bedding, and other stable supplies.

Supplies—Maintenance and Repairs.—This account shall include the cost (1) of supplies used in maintaining and repairing the tipple structure, powerhouse, and other mine buildings and structures, and (2) of supplies and parts used in repairing mining machines, pumps, fans, boilers, engines, motors, locomotives, mine cars, tracks, and other mining equipment.

Here are four separate items for haulage, any one of which might be quoted from a government publication and be misleading as covering only part of the haulage costs.

30. *Itemized Haulage Costs for Typical Large Illinois Mines.*—Table 12 gives transportation costs for twelve mines itemized as suggested by the Coal Association except that the cost of hoisting has been deducted when possible. Two of these mines G and H are also listed in Table 3 of shaft-bottom costs. In general the average daily production of the mines in Table 12 is less than of those in Table 3. The costs per ton in Table 3 apply only to the shaft-bottom labor, whereas the costs in Table 12 cover all haulage labor.

TABLE 12

HAULAGE COSTS AT TWELVE REPRESENTATIVE ILLINOIS COAL MINES

Items	1		2		3		4	
	Labor	Material	Labor	Material	Labor	Material	Labor	Material
(a) Conducting Transportation	$35 737.12	$ 993.20	$ 7 778.49	....	$23 786.80	$ 5 355.33	$16 797.91	$1 522.00
(b) Maintenance of Way	12 238.86	5 997.62	1 028.83 6 566.22	$2 546.34	13 328.05	13 468.21	9 354.47	6 286.98
(c) Generation and Transmission of Power	2 826.92	5 756.42	766.20	....	4 898.54	not given	3 010.51	not given
(d) Care and Maintenance of Equipment	7 302.68	....	1 149.45	681.36	3 048.45	not given	1 636.88	not given
Totals	$58 105.58	$12 747.24	$17 289.19	$3 227.70	$45 061.84	$18 823.54	$30 799.77	$7 808.98
Total Cost	$70 852.82		$20 516.89		$63 885.38		$38 608.75	
Total Cost per Ton	34.10c		25.70c		30.44c		30.65c	
Labor Cost per Ton	28.00c		21.70c		21.47c		24.45c	
Total Tonnage	207 710		79 817		209 889		125 971	
Period	6 mo. 1920		1 mo. 1920		3 mo. 1920		Aug.–Oct. 1920	
Average Daily Tonnage	2600		3400		3100		1700	
System of Haulage: Main Gathering	2 Trolley Loco. 14 Reel Loco.		2 Trolley Loco. 14 S. B. Loco.		4 Trolley Loco. 12 S. B. Loco., 7 Mules		3 Trolley Loco. 6 S. B. Loco., 7 Mules	
Weight Tons Coal per Car	3.30		3.25		3.15		3.00	

TABLE 12 (CONTINUED)

HAULAGE COSTS AT TWELVE REPRESENTATIVE ILLINOIS COAL MINES

Items	5		6		7		8	
	Labor	Material	Labor	Material	Labor	Material	Labor	Materia
(a) Conducting Transportation	$ 9 426.32	$ 650.06	$285.58	....	$ 7 602.28	$ 875.06	$ 6 936.24	....
(b) Maintenance of Way	10 781.47	2 867.57	139.20	3c ton	1 277.79 9 428.36	1 152.55	2 912.98 3 758.59	$1 308.78
(c) Generation and Transmission of Power	180.75	204.83	63.08	7c ton	238.34	not given	248.59	....
(d) Care and Maintenance of Equipment	724.11	820.07	183.03	3c ton	3 508.53	not given	350.90	....
Totals	$21 112.65	$4 542.53	$670.89	13c ton	$22 055.30		$14 207.30	....
Total Cost	$25 655.18		$804.89		$25 924.54		$16 120.98	
Total Cost per Ton	31.62c		44.70c		32.40c		37.40c	
Labor Cost per Ton	26.02c		31.70c		27.60c		33.20c	
Total Tonnage	81 134				79 824		43 013	
Period	Nov. 1920		Aver. day 1920		30 days 1920		Oct. 1920	
Average Daily Tonnage	4000		1800		3200		2250	
System of Haulage: Main Gathering	4 Trolley Loco. 16 S. B. Loco., 4 Mules		3 Trolley Loco. 7 S. B. Loco.		3 Trolley Loco. 15 Reel Loco., 9 Mules		3 Trolley Loco. 22 Mules	
Weight Tons Coal per Car	3.00		2.70		3.25		2.25	

TABLE 12 (CONCLUDED)

HAULAGE COSTS AT TWELVE REPRESENTATIVE ILLINOIS COAL MINES

Items	9		10		11		12	
	Labor	Material	Labor	Material	Labor	Material	Labor	Material
(a) Conducting Transportation	$ 5 173.81	....	$ 9 453.36	$ 927.17	$11 967.20	$1 469.40	$ 9 347.52	$1 806.07
(b) Maintenance of Way	2 503.76 2 224.31	$1 431.71	4 692.88	1 065.57	3 756.11	3 451.86	2 550.35	2 752.12
(c) Generation and Transmission of Power	252.39	....	2 186.54	2 614.95	1 416.88	2 667.06	817.33	3 463.94
(d) Care and Maintenance of Equipment	1 512.19	2 118.68	3 204.43	2 018.26	1 471.25	1 009.30	1 894.72	1 728.96
Totals	$11 666.46	$3 550.39	$19 537.21	$6 625.95	$18 611.44	$8 597.62	$14 609.92	$4 751.09
Total Cost	$15 216.85		$25 163.16		$27 209.06		$24 361.01	
Total Cost per Ton	58.70c		62.70c		77.80c		74.80c	
Labor Cost per Ton	45.00c		48.70c		53.20c		44.90c	
Total Tonnage	25 907		40 115		34 972		32 544	
Period	Oct. 1920		Oct. 1920		Oct. 1920		Oct. 1920	
Average Daily Tonnage	1780		1500		2200		1770	
System of Haulage: Main Gathering	 2 Trolley Loco. 8 Reel Loco.		 4 Trolley Loco. 49 Mules		 4 Trolley Loco. 43 Mules		 4 Trolley Loco. 36 Mules	
Weight Tons Coal per Car	3.25		2.00		2.25		2.20	

The effect of daily production on shaft-bottom costs is shown by Table 3, for the average labor cost per ton in the six largest mines is 26.33 cents while in the six smaller mines it is 41.32 cents. Similarly the average is 39.51 cents as against 58.22 cents in the six smaller mines.

As shown by Table 3, there is cost advantage in handling large cars on the shaft bottom; not only is this cost lowest where the largest cars are used and highest where the smallest cars are used—which might be accidental—but the average cost in four mines where cars holding 4 tons and over are used is 1.31 cents per ton, whereas in 6 mines where cars holding less than 4 tons are used it is 1.51 cents per ton.

In Table 13 hoisting costs are given for comparison with haulage costs. The effect of tonnage upon costs is more pronounced in hoisting than in haulage.

TABLE 13

HAULAGE COSTS AT FIVE MINES OF COMMON OWNERSHIP

In Cents per Ton

Items	Period	I	II	III	IV	V	Averages
Gathering	December, 1920	10.73	10.55	10.61	9.88	13.63	11.08
Main haulage		4.16	2.67	5.80	3.89	4.07	4.12
Track work		4.42	13.91	8.08	17.06	8.03	10.30
Total haulage		19.31	27.13	24.49	30.83	25.73	25.50
Tons mined		47 602	88 018	41 702	73 758	37 928	57 802
Hoisting		1.47	1.09	2.04	1.30	3.81	1.94
Days worked		25.00	26.00	26.00	26.00	25.00	25.60
Gathering	May, 1921	10.60	11.57	12.47	8.73	26.12	13.90
Main haulage		4.05	2.20	6.78	3.20	5.59	4.36
Trackwork		4.98	13.54	9.98	8.88	4.65	8.41
Total haulage		19.63	27.31	29.23	20.81	36.36	26.67
Tons mined		28 921	55 951	28 541	61 121	4 418	35 790
Hoisting		2.44	1.72	2.58	1.89	15.87	4.90
Days worked		13.00	15.00	18.00	20.00	3.00	14.00

In Mines I and V gathering is by mules; in the other mines it is by storage-battery locomotives. All main haulage is by trolley locomotives.

The sub-items considered in obtaining the above costs are as follows:

Trackwork—Tracklayers, helpers, handling track material, grading track (laborers).

Gathering—Mule feeder, blacksmith (part time), drivers, veterinary service, boss driver, motormen on gathering motors, trip riders on gathering motors, battery charger, electrician (part time), labor on repairs, trappers, and flaggers.

Main—Motormen, trip riders, electrician (part time), switch thrower, wiremen (part time), other labor on repairs, trappers and flaggers.

The following are labor costs chargeable to Haulage, exclusive of generation and transmission of power, at an Illinois mine which produces an average of 5000 tons daily:

1 cager	$ 7.50
2 cager helpers	14.50
2 blockers	14.50
2 couplers	14.50
2 oilers	14.50
1 switcher	7.25
2 sump cleaners	14.50
7 drivers	52.50
19 motormen	152.76
19 trip riders	142.50
19 tracklayers	142.50
16 track helpers	116.00
11 repairmen	80.00
4 cleaning falls	30.00
7 brushing	50.75
1 sprinkling roads	7.50
1.5 cleaning roads	12.50
3 hauling dirt	22.50
1 mule feeder	7.50
2 electric bonders	15.00
4 locomotive repairmen	30.00
Total	$949.26
Haulage wage per ton	18.99 cents

Labor, delivery of material and supplies:

1 cager	$ 7.50
1 cager helper	7.25
5 drivers	37.50
Total	$52.25
Daily wage per ton	1.04 cents
Total haulage labor cost per ton	20.03 cents

At another large mine with an average daily output of 5200 tons the average number of employees engaged in haulage operating and in maintenance of way, and their total wages, are as follows:

3 haulage bosses	$ 24.18
29 motormen	233.74
29 trip riders	217.50
32 trappers	128.00
6 jackmen	43.50
6 repairmen	45.00
2 electricians	15.00
1 oiler	7.25
33 tracklayers	247.50
27 track helpers	195.75
18 timbermen	130.50
8 road cleaners	58.00
1 sprinkler	7.50
2 bonders	15.00
4 cagers	29.50
6 blockers	43.50
1 switcher	7.25
2 couplers	14.50
Total	$1463.17
Total haulage wage cost per ton	28.14 cents

At one mine producing 4500 tons daily, the following items cover the daily labor costs of maintaining and conducting haulage:

Maintenance:

1 chief electrician, half time	$ 6.50
1 shop foreman, half time	5.50
1 motor charger, half time	7.50
1 sub-station attendant, half time	4.52
1 motor oiler	7.50
1 electrician	7.50
23 tracklayers at $7.50	172.50
16 track helpers at $7.25	116.00
6 road cleaners at $7.25	43.50
2 sump cleaners at $7.25	14.50
4 car repairers at $7.50	30.00
1 oiler	7.50
Total	$423.02
Total maintenance wages per ton	9.4 cents

Conducting:

16 motormen at $8.06	$128.96
16 trip riders at $7.50	120.00
1 motor boss	11.00
1 cager	7.50
2 spraggers at $7.25	14.50
1 coupler	7.25
1 switcher	7.25
Total	$296.46
Total conducting wages per ton	6.6 cents

This represents high efficiency. No trappers are employed. Double swinging doors are opened automatically by the locomotives, but the item of maintenance of doors is not included in cost.

At this same mine the electric-power costs for haulage for the year 1919 were:

	Kw-hr.
Total kw-hr. used by trolley locomotives	130 210
Total kw-hr. charging battery locomotives	129 650
Total kw-hr. for haulage	259 860

The cost of this power at the rate of 3.5 cents per kilowatt-hour was $9094.10. During the year the mine produced 373 847 tons of coal, thus making the power cost for haulage about 2.4 cents per ton. The complete haulage costs, not including any materials, were per ton:

	Cents
Wages for maintenance	9.4
Wages for conducting	6.6
Power	2.4
Total	18.4

Table 14 details the haulage costs in cents per ton for two large Illinois mines during January and February, 1921.

These two mines operate under similar natural conditions. Mine A has the longer hauls and there is no division between main and gathering haulage, whereas Mine F has two-stage haulage. Although general conclusions must not be drawn from these two mines nor for such a short period, the marked difference in cost between the two systems suggests the desirability of a more extended study of the two systems.

TABLE 14
HAULAGE COSTS AT TWO ILLINOIS COAL MINES
In Cents per Ton

Item	Mine A		Mine F	
	Jan.	Feb.	Jan.	Feb.
Tonnage for month	92 560	62 188	88 072	45 383
Tonnage Daily	4 500	4 480	3 500	3 700
Occupations:				
Motor Bosses	0.63	0.93	0.32	0.62
Motormen	3.54	3.36	4.64	4.43
Trip Riders	2.63	2.64	4.02	3.83
Couplers	0.26	0.29	0.40	0.38
Cagers	0.42	0.48	0.83	0.86
Other Bottom Men	1.16	1.12	0.79	0.72
Flagmen	1.71	1.59	4.26	3.35
Jackmen	0.17	0.17	....	0.13
Maintenance of Way	3.35	2.32	2.68	2.01
Trappers	1.06	0.89	0.50	0.67
Track Bosses	0.26	0.36	....	....
Tracklayers	2.70	2.02	7.21	7.03
Track Helpers	2.35	1.51	4.46	5.03
Totals	20.24	17.68	30.71	29.06
Repairs:				
Labor on Mine Cars	1.92	2.19	3.22	3.31
Supplies for Mine Cars	2.17	2.95	1.07	2.31
Totals	4.09	5.14	4.29	5.62
Labor on Locomotives	1.36	1.43	2.09	2.60
Supplies for Locomotives	1.14	2.38	2.79	2.58
Totals	2.50	3.81	4.88	5.18
Total Cost per Ton Exclusive of Power and Track Equipment	26.83	26.63	39.88	39.86

Table 15 gives the haulage employees and the total labor costs in cents per ton for four large Illinois mines.

The following estimates of haulage wages are for mines having electric haulage exclusively. The figures cited as ranges of costs per ton are distributed under four items. Main-haulage and general wage costs are about equal and each is about double the shaft-bottom wage cost per ton. The labor cost of gathering haulage usually equals or exceeds the sum of the three other items.

Shaft-Bottom Haulage . . . . 1 to 3 cents
Cagers, spraggers, blockers, couplers, car distributors, and all other employees handling cars on shaft bottom only

Main Haulage . . . . 2 to 6 cents
Motormen, trip riders, trappers, trackmen, timbermen, wiremen, road cleaners, switch throwers, etc., engaged directly on main haulage.

Gathering Haulage . . . . 8 to 15 cents
All employees engaged in hauling coal on the inside divisions, including motormen, trip riders, drivers, trappers, and all trackmen and such timbermen as are necessary for maintenance of way.

General . . . . 2 to 6 cents
All employees connected with haulage as a whole, as oilers, electricians (unless strictly main haulage), repairmen, sump cleaners, etc.

Total operating haulage labor cost thus may vary between 13 cents and 30 cents per ton. As the tonnage varies at a given mine on different days there will be a variation in the daily haulage cost per ton, even with the same working force.

TABLE 15

HAULAGE LABOR COSTS AT FOUR LARGE ILLINOIS COAL MINES

In Cents per Ton

Occupations	Mine 1		Mine 2		Mine 3		Mine 4	
	Main	Gather.	Main	Gather.	Main	Gather.	Main	Gather.
Motormen	3	12	4	2	3	15	4	14
Trip Riders	3	12	4	2	3	15	4	14
Tracklayers	11	16	2	8	1	21	7	15
Track Helpers	....	16	2	8	....	....	7	15
Switch Throwers	....	....	....	5	....	....	1	....
Wiremen	....	....	1	....	....	....	....	....
Trappers	....	....	4	9	....	....	....	14
Timbermen	....	....	4	2	....	....	....	....
Drivers	....	....	....	12	....	....	....	....
Batterymen	....	2	....	....	....	....	....	4
Mule Feeders	....	....	....	....	....	....	....	2
Road Cleaners	1	....	....	....	....	....	....	1
Totals	18	58	21	48	7	53	23	79
Total Cost Labor	$131.41	$437.48	$144.41	$283.08	$54.12	$405.10	$172.10	$542.27
Tonnage Daily	4500		3800		3400		4000	
Labor cost per ton:								
Main	3.0	....	3.8	....	1.6	....	4.3	....
Gather	....	9.7	....	7.4	....	12.0	....	13.5
Total per Ton, cents	12.7		11.2		13.6		17.8	

VI. Haulage Accidents

31. *Haulage Fatality Statistics.*—Table 16 gives the coal mine haulage fatalities in the United States and in Illinois for the period 1901 to 1920 inclusive, together with the average percentage of all fatalities for each five-year period. For the past ten years haulage fatalities have been second in importance only to those from falls. These two classes, which make up from 60 to 70 per cent of the number of deaths underground, occur for the most part singly or in small groups, hence do not attract public attention to the same extent as do explosions, which are third in importance. The number of deaths from falls is remarkably uniform year after year, forming almost 50 per cent of the total fatalities. Haulage deaths have been constantly increasing in per cent of the total and therefore should be given more attention as they seem to a great extent to be preventable.

In Illinois the percentage of deaths from falls of roof and pillar coal approximates that for the United States but the percentage of deaths from haulage is higher and shows a decided increase during the past decade. Such haulage fatalities are due not only to mine cars and locomotives but also to electricity and animals as shown in Table 17.

Table 16

Coal Mine Fatalities due to Haulage

By Five-Year Periods

Period	United States			Illinois		
	Total Underground Fatalities	Haulage Fatalities	Per Cent of Total	Total Underground Fatalities	Haulage Fatalities	Per Cent of Total
1901–1905......	8 428	1097	13.0	668	84	12.6
1906–1910......	12 017	1649	13.7	1024	145	14.2
1911–1915......	11 424	1939	17.0	753	191	25.4
1916–1920......	10 771	2201	20.4	904	278	30.8
Totals 1901–1920	42 640	6886	16.1	3349	698	20.8

TABLE 17

UNITED STATES COAL-MINE FATALITIES DUE TO HAULAGE CLASSIFIED AS TO CAUSES

Causes	Year				
	1916	1917	1918	1919	1920
1. Mine Cars and Locomotives:					
Switching and Spragging	17	6	15	12	6
Coupling Cars	12	7	11	6	13
Falling from Trips	43	29	36	17	26
Run over by Car or Locomotive	147	187	203	149	163
Caught between Car and Rib	87	122	113	105	98
Caught between Car and Roof	12	20	27	23	18
Runaway Car or Trip	42	67	68	42	43
Miscellaneous	30	50	33	27	38
Totals	390	488	506	381	405
2. Electricity:					
Direct Contact with Trolley Wire	66	46	55	39	29
Bar or Tool Striking Trolley Wire	5	2	4	2	3
Contact with Locomotive Parts	1	4	1	2	3
Totals	72	52	60	43	35
3. Animals	8	9	8	2	4
Total Fatalities Chargeable to Haulage	470	549	574	426	444
Total Fatalities Due to Coal Mining	2226	2696	2580	2317	2260
Per Cent Due to Haulage	21.1	20.4	20.2	18.4	19.7

Even falls are frequently caused initially by derailed cars knocking out roof supports.

Table 17 gives the classification of the causes of haulage fatalities in the United States for the five-year period, 1916-1920.

32. *Haulage Accidents in Illinois.*—Table 18 gives a more detailed causal analysis of haulage accidents for Illinois, and the accompanying graph, Fig. 27, shows the variation of the percentages of haulage to total fatalities throughout the period 1902-1921. The latter half of the period is fairly indicative of present operating conditions. For the past ten years haulage fatalities have averaged 27 per cent of the whole. During the years 1918 to 1921 inclusive the average number of employees in Illinois coal mines was 88 274 per year. These

TABLE 18

CAUSAL ANALYSIS OF HAULAGE FATALITIES IN ILLINOIS

Causes	Period					
	1902–05	1906–10	1911–15	1916–20	1921	Totals
Switching and Spragging	5	8	5	7	1	26
Coupling Cars	1	1	5	13	3	23
Falling from Trips	11	39	31	22	3	106
Run over by Car or Locomotive	12	15	29	72	24	152
Caught between Car and Rib	9	12	20	29	4	74
Caught between Car and Face	0	0	0	4	0	4
Caught between Car and Roof	5	9	4	7	2	25
Caught between Cars (not Coupling)	7	11	2	10	3	33
Runaway Car or Trip	3	10	7	11	0	31
Jumping on or off Car or Locomotive	2	3	8	11	0	24
Collisions	3	6	5	8	3	25
Derailments	7	6	13	15	2	43
Killed by Cars, not Stated	5	5	62	54	8	134
Roof Falls	1	0	1	0	8	10
Animals	1	7	8	7	0	23
Contact Trolley Wire	2	4	12	18	3	39
Miscellaneous	1	3	1	4	1	10
Total Haulage Fatalities	75	139	213	292	65	782
Total Coal-mining Fatalities	611	1122	856	1020	222	3831
Per Cent Haulage Fatalities	12.3	12.4	24.9	28.6	29.3	20.4

four years are selected because they represent recent average conditions and the statistics are complete. The average number of haulage employees per year was 12 493; hence the duties of mine haulage required more than one-seventh of the entire number of coal mine workers in the state. For these same years in Illinois there were 243 fatalities directly attributable to haulage as against 870 total coal-mine fatalities. These fatalities averaged respectively, 60.75 and 217.5 annually. Since 60.75 haulage fatalities were sustained among 88 274 employees, this was 1 for each 1453 men employed about coal mines.

Even among those 75 781 employees who positively had no duties connected with haulage, Table 19 shows that the annual haulage fatalities for this same four-year period averaged 19.25, or one in 3937, thus leaving an average of 41.5 haulage employees killed each year in the discharge of their duties. There being 12 493 such employees, it follows that the mortality was one per 301 men.

The number of deaths occurring year by year naturally increases with increase in production and number of men engaged. Thus, as shown in Table 19, while the production has increased rapidly, it has always been more than 1 000 000 tons of coal per fatal haulage accident, the best record being in 1905, slightly more than 3 000 000 tons, and the lowest in 1913, 1 124 476 tons. The average for the whole period is about 1 500 000 tons.

The graph, Fig. 28, shows a periodicity in the fatalities directly attributable to underground haulage. It can be seen that the peaks and depressions do not coincide with similar features of the curve for total coal-mining fatalities, Fig. 27. The large numbers of fatal

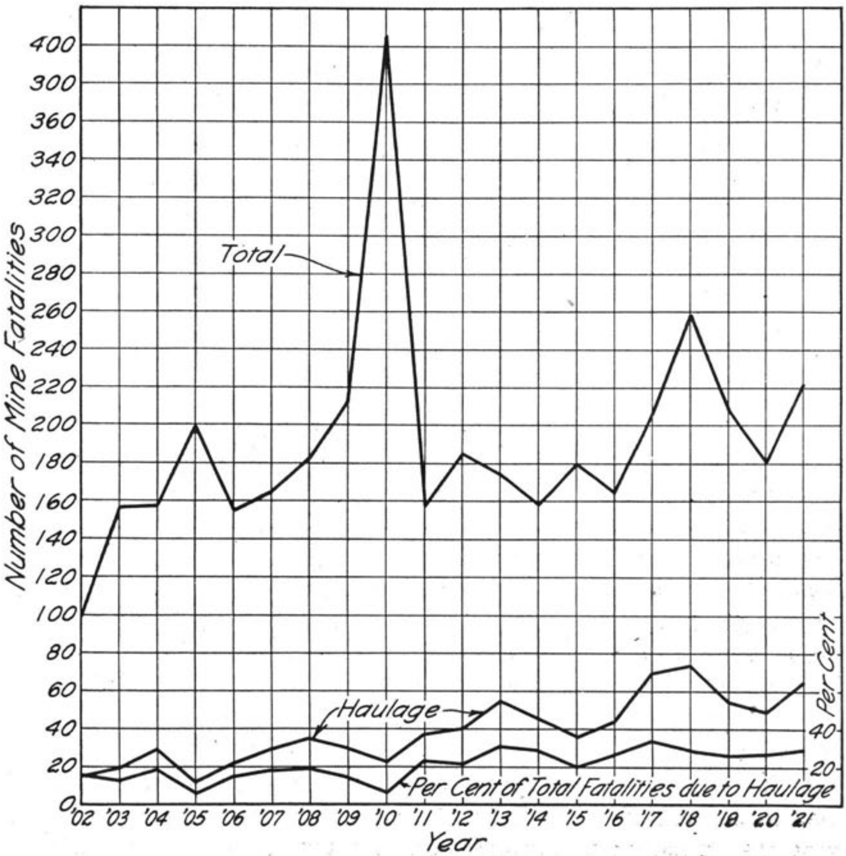

FIG. 27. GRAPH OF ILLINOIS COAL MINE FATALITIES

TABLE 19

RELATION BETWEEN COAL PRODUCTION AND HAULAGE FATALITIES IN ILLINOIS

Year	Production	Total Haulage Fatalities	Total Fatalities Haulage Employees	Fatalities Non-Haulage Employees	Fatalities to Drivers		Fatalities to Motormen and Trip Riders		Tons per Haulage Fatality
					No.	Per Cent	No.	Per Cent	
1902	30 021 300	15	13	2	10	66.70	..	.....	2 001 420
1903	34 955 400	19	15	4	14	73.11	..	.....	1 839 757
1904	37 077 897	29	21	8	16	55.17	..	.....	1 278 544
1905	37 183 374	12	9	3	8	66.66	..	.....	3 098 614
1906	38 317 581	22	18	4	15	68.18	1	4.54	1 741 708
1907	47 798 621	29	22	7	17	58.62	1	3.44	1 648 228
1908	49 272 452	35	31	4	25	71.42	..	.....	1 407 784
1909	49 163 710	30	23	7	18	60.00	2	6.66	1 638 790
1910	48 717 853	23	23	0	20	86.95	1	4.34	2 118 170
1911	50 165 099	37	30	7	22	59.45	3	8.10	1 355 813
1912	57 514 240	40	32	8	20	50.00	5	12.50	1 437 856
1913	61 846 204	55	37	18	22	40.00	6	10.90	1 124 476
1914	60 715 795	45	35	10	20	44.44	10	22.22	1 350 352
1915	57 601 694	36	25	11	13	36.11	9	25.00	1 600 047
1916	63 673 530	44	29	15	18	40.90	5	11.36	1 446 443
1917	78 983 527	70	48	22	28	40.00	14	20.00	1 128 336
1918	89 979 469	74	51	23	20	26.66	21	28.00	1 199 726
1919	75 099 784	55	36	19	14	25.00	16	28.57	1 341 067
1920	73 920 653	49	25	24	9	18.38	7	14.29	1 508 585
1921	80 121 948	65	54	11	18	27.69	28	43.08	1 232 645
Ave. and Totals	1 122 130 131	784	577	207	347	44.25	129	16.45	1 431 287

accidents that occurred in 1905, 1910, and 1915 were caused by serious disasters such as fires and explosions but it would seem that haulage employees suffered least of all the classes of underground employees. The peaks in the curve for haulage fatalities, Fig. 28, preceded the peaks of total fatalities by a year or two in each instance and the question suggests itself, did not the haulage employees naturally become more careful after each time of heavy loss and in consequence conduct their duties with special attention to "safety first"?

The relative hazards incident to the occupations of those killed in connection with haulage are shown by Table 20 and the graph, Fig. 29. It can be expected that with the more extended use of mechanical haulage, with increased speed and size of equipment, and with the utilization of haulage ways as traveling ways, the hazard to employees other than haulage employees will be increased. During the period 1902 to 1921, inclusive, non-haulage employees sustained 28.8 per cent of the total haulage fatalities, as shown by Table 20.

Since 1915 the number of non-haulage employees killed each year has exceeded the number of motormen and trip riders killed; and, since 1918, has even exceeded the number of drivers or motormen and trip riders killed—the largest groups among haulage employees. The classes of employees included in haulage fatalities are given in Table 20 in which the first ten occupations are essentially connected with haulage. It seems that the accidents to non-haulage employees can be most readily prevented and should be given special attention.

Table 21 gives a comparison of the haulage hazard for various counties in the state for a period of nine years. As Franklin county not only has the largest number of fatalities per million tons, but is now the largest producing county in the state, a detailed study of the casualties in that county was made (Table 22). Of the mine fatalities

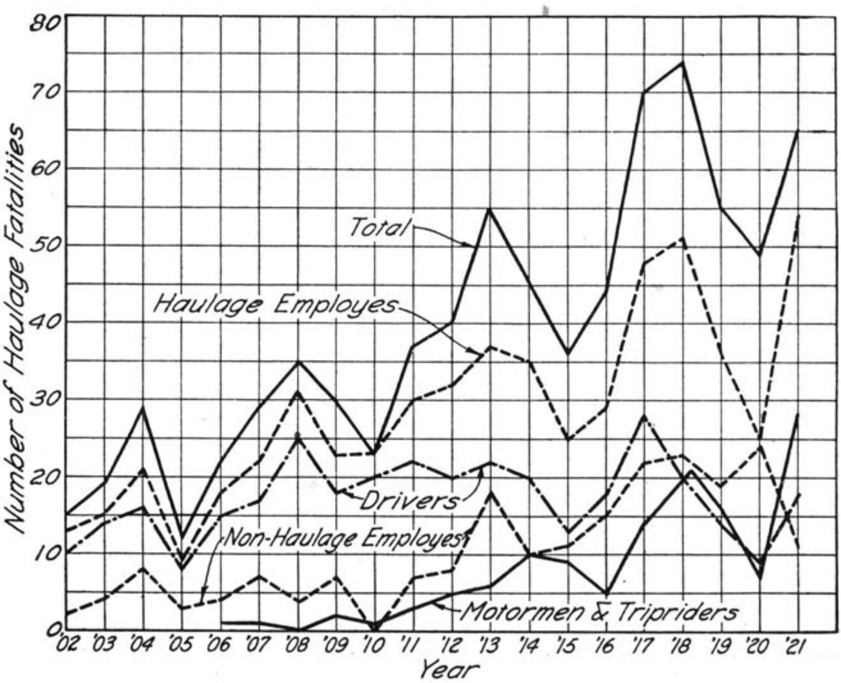

FIG. 28. GRAPH OF ILLINOIS COAL MINE HAULAGE FATALITIES

TABLE 20

HAULAGE FATALITIES IN ILLINOIS—CLASSIFIED BY OCCUPATIONS

Occupations	Period					
Haulage Employees:	1902–05	1906–10	1911–15	1916–20	1921	Totals
Drivers	48	95	97	89	18	347
Trip Riders	0	5	24	44	19	92
Trappers	6	7	11	16	5	45
Motormen	0	0	9	17	9	35
Track and Road Men	2	2	3	9	2	18
Spraggers	1	2	1	1	1	6
Switchmen	0	1	2	2	0	5
Couplers	0	1	1	3	0	5
Electricians	0	0	0	4	0	4
Grippers	0	1	0	0	0	1
Total Haulage Employees	57	114	148	185	54	558
Non-Haulage Employees:						
Miners	14	12	38	59	7	130
Laborers	2	8	11	17	1	39
Managers and Assistants	1	1	4	12	1	19
Cagers	0	3	9	5	1	18
Timbermen	0	1	2	4	1	8
Pipemen and Pumpmen	0	0	0	3	0	3
Machine Runners	0	0	0	2	0	2
Bratticemen	0	0	0	2	0	2
Blacksmiths	0	0	0	2	0	2
Hoist Engineers	1	0	0	0	0	1
Shot-firers	0	0	0	1	0	1
Mining Engineers	0	0	1	0	0	1
Total Non-Haulage, Employees	18	25	65	107	11	226
Total Fatalities	75	139	213	292	65	784
Per Cent, Haulage Employees	76.0	82.0	69.5	63.4	83.1	71.2
Per Cent, Non-Haulage Employees	24.0	18.0	30.5	36.6	16.9	28.8

in Franklin county during 15 recent years, 22 per cent have been due to haulage, while during the last five years 28 per cent have been due to the same cause. Undoubtedly, large producing mines, large capacity cars, and high speed are the chief reasons for the increased number of haulage fatalities.

Table 23 presents statistics for one year for the non-fatal accidents that occurred in a selected group of typical Illinois coal mines. In this same year, 1919, the total number was 2620, so that roughly speaking this table covers one-third of all such accidents in the state.

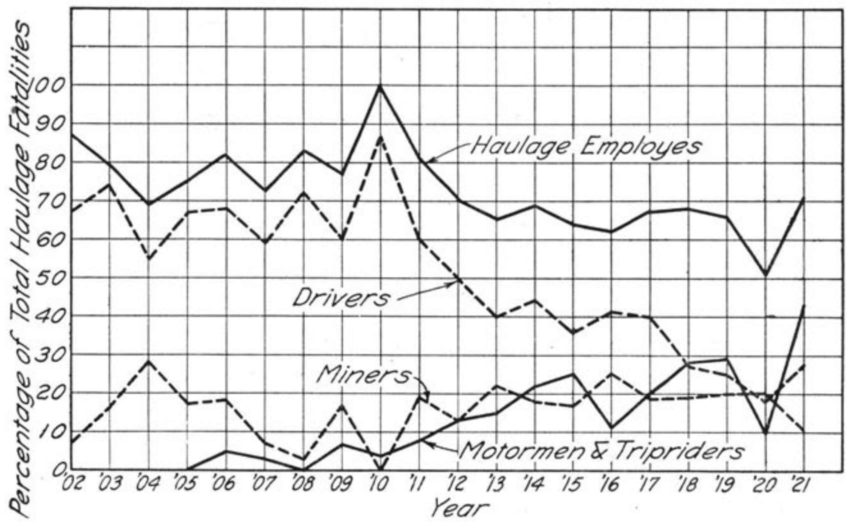

FIG. 29. GRAPH SHOWING PERCENTAGES OF FATALITIES BY OCCUPATIONS

TABLE 21

RELATION OF HAULAGE FATALITIES TO PRODUCTION
For Period of Nine Years in 19 Coal-Mining Counties of Illinois

County	Tonnage	Fatalities	Fatalities per Million Tons
Franklin	69 263 400	97	1.40
Montgomery	26 259 295	29	1.10
Jackson	6 948 458	7	1.01
Vermilion	26 908 926	24	0.90
Williamson	80 906 264	72	0.89
Saline	38 700 228	33	0.83
Fulton	19 595 117	14	0.71
Christian	18 901 802	13	0.70
Madison	35 766 010	25	0.69
Sangamon	53 303 653	36	0.68
Macoupin	49 194 248	33	0.67
Washington	4 483 649	3	0.67
Perry	19 182 399	12	0.62
La Salle-Bureau*	39 369 969	21	0.53
St. Clair	43 627 890	19	0.44
Peoria	9 773 729	4	0.41
Clinton	10 988 907	4	0.36
Randolph	9 103 527	1	0.11
Marion	9 453 052	0	0.00
Totals	570 730 523	447	0.78
Bal. of State	24 848 819	9	0.36
Total of State	595 579 342	456	0.76

*Northern Longwall Field

TABLE 22
FATALITIES IN COAL MINING, FRANKLIN COUNTY, ILLINOIS
For 17-year Period

Cause	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	17-Year Period		Last 5 Years	
																		Total	Per Cent	Total	Per Cen
Falls, Coal, Rock	1	1	0	3	2	3	4	7	11	11	4	10	8	11	8	10	14	108	20.3	51	22.5
Cars, Locomotives	0	1	0	1	2	4	3	4	6	6	8	9	20	19	18	15	11	128	24.0	83	36.6
Explosions	50	0	0	4	43	3	0	0	1	1	54	9	2	21	24	0	2	214	40.2	49	21.6
Electricity	0	0	1	0	0	2	0	1	0	1	1	2	1	5	0	2	2	18	3.4	10	4.4
Miscellaneous	1	0	0	0	2	0	2	0	0	1	1	0	1	0	0	3	0	11	2.1	4	1.7
Shaft	0	3	0	2	0	1	0	0	5	1	0	1	0	8	3	2	1	27	5.1	14	6.2
Surface	0	0	0	1	0	0	0	0	0	0	2	2	5	0	2	4	3	18	3.4	14	6.2
Explosives	0	1	1	1	0	0	0	0	2	0	1	0	0	0	0	2	0	8	1.5	2	0.8
Totals	52	6	2	12	49	13	9	12	25	21	71	33	37	64	55	33	38	532	100.0	227	100.0

TABLE 23

NON-FATAL ACCIDENTS FOR GROUP OF ILLINOIS MINES, FOR YEAR 1919

Occupations	No. Injured	No. Shifts Lost
Haulage Employees:		
Motormen	44	1 011
Trip Riders	112	3 448
Trappers, Spraggers	15	301
Couplers	10	440
Trackmen	26	689
Electricians	20	352
Total Haulage Employees	227	6 241
Other Underground Employees	572	15 869
Surface Employees	71	1 485
Total Non-Fatal Accidents	870	23 595
Per Cent, Haulage Employees	26.1	26.4

Comparing injuries by the relative losses of time sustained by the victims, the average time lost per accident was 27.1 shifts, this applying to all occupations of coal mining, both underground and surface. Although the electricians' duties should properly be distributed between haulage, coal-cutting, and illumination, they are charged to haulage exclusively. On this basis, we have a total number of 227 injuries that caused a loss of 6241 shifts or approximately 27.5 shifts per accident. The significance of this analysis is that the injuries sustained from haulage appear to be about equal in severity to the average of all coal-mining non-fatal injuries. This of course has no direct bearing upon relative hazards nor upon fatalities. This appears in a different manner in the last line of Table 23 which shows that haulage employees sustained not only 26.1 per cent of the accidents but also 26.4 per cent of the lost time.

Table 24 is presented to compare coal mine haulage fatalities in Illinois with those in the bituminous district of Pennsylvania. The Pennsylvania data are from the Statistical Analysis of Coal Mine Accidents compiled by the Insurance Department of Pennsylvania. This table covers the 5-year period, 1916-1920, thus representing present conditions, and shows production tonnages for several classes of employees. Pennsylvania produced more than twice as much coal as did Illinois with about twice as many coal-mine employees. Various interesting comparisons may be noted in the column of Ratios.

TABLE 24

UNDERGROUND HAULAGE FATALITIES IN BITUMINOUS MINES OF PENNSYLVANIA AND ILLINOIS

5-Year Period, 1916-1920

Items	Pa.	Ill.	Ratios	Comments
Total Coal Production	831 877 000	381 656 963	2.18 : 1	
Total No. Men Employed	864 878	427 273	2.02 : 1	Pa. double Ill.
Tons Coal per Employee	961.8	893.2	1.07 : 1	Close
Haulage Fatalities:				
Total	557	292	1.91 : 1	Almost 2 : 1
To Non-Haulage Employees	221	103	2.14 : 1	Parallel with production
To all Haulage Employees	318	189	1.68 : 1	5 : 3
To Loco. Employees	209	61	3.43 : 1	Notable difference
To Mule Drivers	99	89	1.11 : 1	Nearly even
Percentage of Haulage Fatalities:				
Suffered by Haulage Employees	57.09	64.72	1 : 1.13	
Suffered by Loco. Employees	65.72	32.27	2.03 : 1	Pa. double Ill.
Suffered by Mule Drivers	31.13	47.09	1 : 1.51	Ill. 51 per cent greater
Tons of Coal Produced for each Fatality:				
Haulage	1 493 495	1 307 044	1.14 : 1	
Haulage Employee	2 615 965	2 019 349	1.29 : 1	
Loco. Employee	3 980 272	6 256 671	1 : 1.57	
Mule Driver	8 402 798	4 288 280	1.96 : 1	Pa. double Ill.
Non-Haulage Employees	3 764 149	3 705 407	1.01 : 1	Practically equal
No. of Employees for each Fatality:				
Due to Haulage	1552.7	1463.3	1.06 : 1	
To Haulage Employees	2719.7	2260.7	1.20 : 1	
To Non-Haulage Employes	2913.5	4148.3	1 : 1.42	
To Loco. Employees	4138.2	7004.5	1 : 1.69	
To Mule Drivers	8736.1	4800.8	1.82 : 1	

33. *Comparative Hazards in Locomotive and Animal Haulage.*—The question arises as to whether or not locomotive haulage is more dangerous than animal haulage. Analysis of Illinois statistics on this subject shows that a direct answer to the inquiry is imposible, but the statistics in the Annual Coal Report of Illinois for the year 1921 may be accepted as fairly representative of present-day conditions. In that year there were in the coal mines 2892 locomotive men, 4229 drivers, and 278 boss drivers. Of all classes of underground employees, numbering 81 708, 39 men were killed by locomotive haulage and

26 men by animal haulage, a total of 65 fatalities (see Table 19). Of these 65 fatalities, 54 were among the 23 453 employees connected with haulage. There were 7399 men employed in moving trips of coal, 2892 of these being motormen and trip riders and the remaining 4507, mule drivers. Of the 54 haulage-employee victims 8 were men other than trip men (5 trappers, 2 tracklayers, and 1 spragger), 28 were locomotive men, and 18 were drivers (see Table 20). Beside the 7399 trip men, there were 6054 haulage employees such as trappers, spraggers, trackmen, stablemen and electricians. (In the case of electricians it is assumed that about one-half their time is occupied with mining work connected with mining machines, illumination and pumping.) There were 19 haulage fatalities among the 74 309 employees other than trip men. Of these 17 were due to locomotive haulage and 2 to mule haulage. In 1921 there were 2.03 locomotive men per locomotive and 1.19 mules per driver.

From the above data several deductions are possible:

(a) Of the 4507 drivers and boss drivers 18 were killed in their occupation. This is a rate of 3.994 men per thousand.

(b) Of the 2892 locomotive men 28 met death in their duties, this being a rate of one man per 103 men or 9.682 men per thousand.

(c) Locomotive men were thus under a hazard 2.42 times greater than were mule drivers.

(d) Among all classes of underground employees, locomotive haulage, with its 39 fatalities, was but one and one-half times as dangerous as mule haulage with its 26 fatalities.

(e) Among the 74 309 employees other than trip men (motormen, trip riders, drivers) fatalities were 19, this being a rate of one death per 3911 men or 0.256 men per thousand. The risk assumed by such workmen appears reasonably small. In comparing the 17 locomotive haulage fatalities with the 2 fatalities due to mule haulage we run upon the striking fact that, to nearly 91 per cent of all underground employees, locomotive haulage is eight and one-half times as dangerous as mule haulage.

Such calculations and deductions, however—leading to the conclusion that locomotive haulage is much more dangerous than mule haulage—have been based upon the numbers of employees only, whereas recent practice refers vital coal-mine statistics to tonnage of production.

There is a slow but general lessening of mule haulage on main lines. The last statistics gathered on this point—those for the year 1921—show that mules hauled less than one-tenth as much coal over main lines as did locomotives. The superiority of locomotives over mules for main haulage became fully evident to Illinois coal operators about fifteen years ago. Mules handled their maximum annual tonnage on main roads in 1907. Since that year, there has been a general diminution of this mule haulage with a simultaneous increase in the annual tonnage handled on main roads by locomotives. Using data from Table 1 and Table 19 for the years 1908 to 1921 inclusive, we find that for a total of 674 766 930 tons of coal hauled by locomotives on main lines there were 334 fatalities and that for 185 986 960 tons hauled by mules there were 321 fatalities. This means that the respective tonnages per fatality were 2 020 260 and 579 398 and indicates that mule haulage is nearly 3.5 times as dangerous as locomotive haulage when computed from the standpoint of tonnage handled.

34. *Accident Prevention Measures.*—The safeguards or measures installed to prevent accidents are usually determined by their relative necessity. Generally speaking favorable natural conditions of haulage, with easy grades and good roadbed, standard haulage equipment in good repair, and strict enforcement of safe practices are prime requisites for safe haulage and efficient operation. There are dangers inherent to such acts as switching, spragging, coupling, jumping on and off cars and locomotives, and handling animals, but these risks may be minimized by strict adherence to and practice of safety-first principles. If these accidents are due to inadequate or poorly maintained equipment or to failure to inculcate safety principles among the employees, certain responsibilities must be assumed by mine owners. It is not, however, the purpose of this discussion to decide upon specific methods of minimizing the accident hazards that attend mine haulage but to study the occurrence and relative numbers of such hazards in the different occupations. When each operator duly analyzes the accidents that occur in his mine he will be in position to undertake corrective measures that will apply to his particular property. The frequent recurrence of accidents to a given group of workers emphasizes the need of accident-prevention regulations for that group. Statistics covering a period of years reveal the underlying

causes, and from them may be formulated more effective methods of combating the hazards.

For example, as the work of distributing and collecting cars underground must be maintained with a certain amount of speed, narrow haulageways with scant illumination are constant sources of danger. This hazard increases with the speed of haulage. In order to reduce this risk whitewash is applied to the walls and roofs of shaft bottoms in the larger mines of the state. The benefit of this treatment is especially marked in bottoms without concrete linings, but it is considerable even where concrete supports are erected. Mine superintendents believe that their men work more freely and cheerfully in the better illumination and that there are fewer accidents. Whitewash, moreover, possesses sanitary features that recommend its use in stables, first-aid rooms, offices, and waiting-rooms. Along main-haulage roads whitewash should be used in all manholes or refuges and upon all doors, as means of additional safety to employees. At partings and at all entry branchings in portions of mines remote from electrical lighting, whitewashed ribs and roofs greatly enhance the illumination and thus reduce accident hazards. There are several recipes for making whitewash which has the properties desired in underground use. The washes may be applied by either brushes or sprays—preferably the latter. Two or three coats should be applied with intermissions for due seasoning.

In all districts the personal factor is often the controlling element. It is generally agreed that such accidents as those due to falls, haulage, and handling explosives, have much in common and that mental and physical alertness and knowledge of the hazards are the essential safeguards. Workmen grow thoughtless of their own personal interests when continually subjected to dangers. It is very probable that the majority of the deaths classified by causes in Table 18 were due to carelessness of the victims themselves. The final responsibility is therefore placed to a very great extent on the individual worker.

35. *Safety Rules for Underground Haulage.*—Keep locomotives, cars and track equipment in good repair.

Standardize car equipment, such as bumpers and couplings.

Illuminate haulage ways so that men need not carry individual lights on motor tracks.

Have head-lights on locomotives and markers, gongs or lights on rear cars of trips.

Have safe clearance between cars and one or preferably both ribs of entry.

Maintain whitewashed refuge holes at regular intervals.

Use block fillers to top of rail-web in flangeways and wedge-spaces in frogs and switches.

Use low-voltage trolley current; support wire at short intervals, so that sag will not exceed 3 inches; guard trolley with boxing 3 inches lower than wires, especially where men travel, as at junctions and stations where man-trips are made up.

Start locomotives only on signal from trip riders and after giving warning bells. Ring bells before all junctions.

Keep car-doors and latches in repair and inspect reclosing.

Give special instructions for spragging and blocking cars.

Place limitations on speed of travel.

Maintain special instruction for motormen and trip riders regarding the making-up of trips.

Give instructions in coupling cars.

Impress on all working in the mine the necessity of personal caution.

PUBLICATIONS OF THE ILLINOIS COAL MINING INVESTIGATIONS

Bulletin 1. Preliminary Report on Organization and Method of Investigations. 1913. *None available.*

Bulletin 2. Coal Mining Practice in District VIII (Danville), by S. O. Andros. 1913. *None available.*

Bulletin 3. Chemical Study of Illinois Coals, by S. W. Parr. 1916. *None available.*

Bulletin 4. Coal Mining Practice in District VII (Mines in bed 6 in Bond, Clinton, Christian, Macoupin, Madison, Marion, Montgomery, Moultrie, Perry, Randolph, St. Clair, Sangamon, Shelby, and Washington counties), by S. O. Andros. 1914. *None available.*

Bulletin 5. Coal Mining Practice in District I (Longwall), by S. O. Andros. 1914. *None available.*

Bulletin 6. Coal Mining Practice in District V (Mines in bed 5 in Saline and Gallatin counties), by S. O. Andros. 1914. *Free upon request.*

Bulletin 7. Coal Mining Practice in District II (Mines in bed 2 in Jackson County), by S. O. Andros. 1914. *Free upon request.*

Bulletin 8. Coal Mining Practice in District VI (Mines in bed 6 in Franklin, Jackson, Perry, and Williamson counties), by S. O. Andros. 1914. *Free upon request.*

Bulletin 9. Coal Mining Practice in District III (Mines in beds 1 and 2 in Brown, Calhoun, Cass, Fulton, Greene, Hancock, Henry, Jersey, Knox, McDonough, Mercer, Morgan, Rock Island, Schuyler, Scott, and Warren counties), by S. O. Andros. 1915. *Free upon request.*

Bulletin 10. Coal Resources of District I (Longwall), by G. H. Cady. 1915. *None available.*

Bulletin 11. Coal Resources of District VII (Counties listed in Bulletin 4), by Fred H. Kay. 1915. *None available.*

Bulletin 12. Coal Mining Practice in District IV (Mines in bed 5 in Cass, DeWitt, Fulton, Knox, Logan, Macon, Mason, McLean, Menard, Peoria, Sangamon, Schuyler, Tazewell, and Woodford counties), by S. O. Andros. 1915. *Free upon request.*

Bulletin 13. Coal Mining in Illinois, by S. O. Andros. 1915. *Free upon request.*

Bulletin 14. Coal Resources of District VIII (Danville), by Fred H. Kay and K. D. White. 1915. *Postage four cents.*

Bulletin 15. Coal Resources of District VI, by G. H. Cady. 1916. *Fifteen cents.*

Bulletin 16. Coal Resources of District II, by G. H. Cady. 1917. *Fifteen cents.*

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Bulletin 26. Coal Resources of District IV (Peoria-Springfield), by G. H. Cady. 1921. Mailing weight, 2 pounds.

***Bulletin** 72. U. S. Bureau of Mines, Occurrence of Explosive Gases in Coal Mines, by N. H. Darton. 1915. *Thirty-five cents.*

***Bulletin** 83. U. S. Bureau of Mines, The Humidity of Mine Air, by R. Y. Williams. 1914. *Ten cents.*

***Bulletin** 99. U. S. Bureau of Mines, Mine Ventilation Stoppings, by R. Y. Williams. 1915.

***Bulletin** 102. U. S. Bureau of Mines, The Inflammability of Illinois Coal Dusts, by J. K. Clement and L. A. Scholl, Jr. 1916.

***Bulletin** 137. U. S. Bureau of Mines, The Use of Permissible Explosives in the Coal Mines of Illinois, by James R. Fleming and John W. Koster. 1917.

***Bulletin** 138. U. S. Bureau of Mines, Coking of Illinois Coals, by F. K. Ovitz. 1917. *Twenty cents.*

***Technical Paper** 190. U. S. Bureau of Mines, Methane Accumulations from Interrupted Ventilation, with Special Reference to Coal Mines in Illinois and Indiana, by Howard J. Smith and Robert J. Hamon, 1918.

***Technical Paper** 246. Water-gas Apparatus and the Use of Central District Coal as Generator Fuel, by W. W. Odell. 1921. *Five cents.*

***Technical Paper** 268. Preparation and Uses of Tar and its Simple Crude Derivatives. W. W. Odell. 1922.

Bulletin 91. Engineering Experiment Station, University of Illinois, Subsidence Resulting from Mining, by L. E. Young and H. H. Stoek. 1916. *None available.*

Bulletin 100. Engineering Experiment Station, University of Illinois, The Percentage of Extraction of Bituminous Coal, with Special Reference to Illinois Conditions, by C. M. Young. 1917. *Free upon request.*

Bulletin 113. Engineering Experiment Station, University of Illinois, Panel System of Coal Mining, A Graphical Study of Percentages of Extraction, by C. M. Young. 1919. *Free upon request.*

Bulletin 119. Engineering Experiment Station, University of Illinois, Some Conditions Affecting the Usefulness of Iron Oxide for City Gas Purification, by W. A. Dunkley. 1921. *Free upon request.*

Bulletin 125. Engineering Experiment Station, University of Illinois, The Distribution of the Forms of Sulphur in the Coal Bed, by H. F. Yancey and Thomas Fraser. 1921. *Free upon request.*

Bulletin 132. Engineering Experiment Station, University of Illinois, A Study of Coal Mine Haulage in Illinois, by H. H. Stoek, J. R. Fleming, and A. J. Hoskin. 1922. *Free upon request.*

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